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ABSTRACT

The development of differential vowel duration was observed in six children who were tape recorded at 1-month intervals from 26 to 36 months of age and in three children from 21 to 24 months of age. By differential vowel duration is meant the relatively different durations of vowels according to whether the following consonant is voiced or voiceless, stop or fricative. The children's task was to produce a series of consonant-vowel-consonant English words using each of the vowels /I i u/ before one voiceless and one voiced fricative. Four stimulus conditions were used: a visual stimulus using familiar storybook pictures and three sets of tape-recorded stimuli with the vowel /i/. One set had normal differential vowel duration, another had abnormal equal vowel duration, and the third had four occurrences of each word with graded vowel durations. Results showed that acquisition of differential vowel duration preceded control of the voicing feature which conditions it in adult English. Correct intrinsic vowel duration was produced in all responses. This document, Part 1, includes the introduction and reports of three stimulus conditions. The report concludes with Part 2, which can be found in document RE 003 492. Tables are included. (Author/DH)

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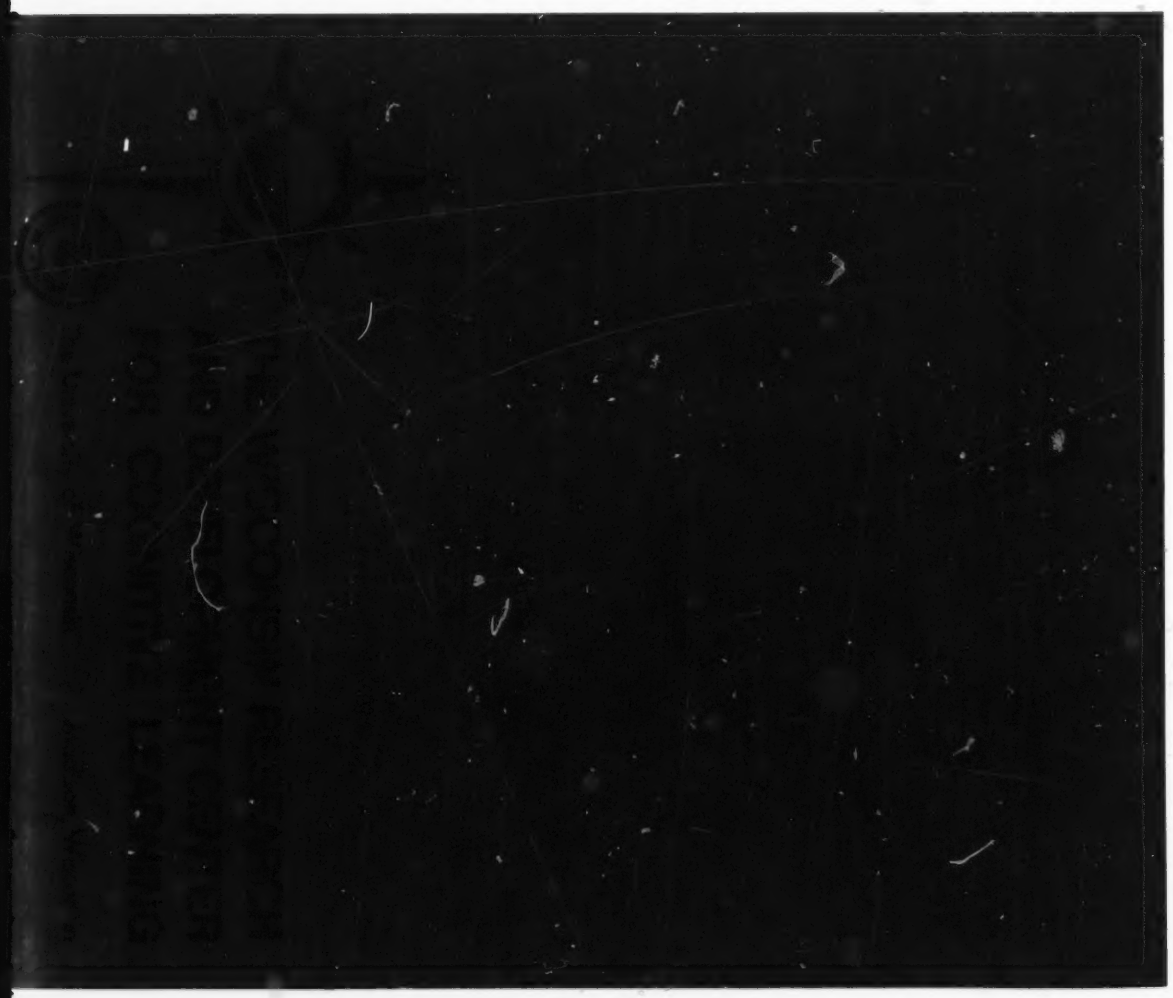

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Technical Report No. 144 (Part 1 of Two Parts)

THE AMERICAN CHILD'S ACQUISITION OF DIFFERENTIAL VOWEL DURATION

Report from the Project on
Basic Pre-Reading Skills:
Identification and Improvement

By Margaret A. Naeser

Jeanette Johnson Harries, Assistant Professor of Linguistics
Chairman of the Examining Committee

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RE 003 491

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

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STATEMENT OF FOCUS

The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are disigned for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This Technical report is from the Basic Pre-Reading Skills: Identification and Improvement Project in Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by prior activities. Contributing to these Program objectives, this project's basic goal is to determine the processes by which children aged 4 to 7 learn to read, examining the development of related cognitive and language skills, and to identify the specific reasons why many children fail to learn to read. Later studies will be conducted to find experimental techniques and tests for optimizing the acquisition of skills needed for learning to read. By-products of this research program include methodological innovations in testing paradigms and measurement procedures; the present study is an example.

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Abstract

The development of differential vowel duration was observed in six children who were tape recorded at one-month intervals from 26 to 36 months of age, and in three children from 21 to 24 months of age. By differential vowel duration is meant the relatively different durations of vowels according to whether the following consonant is voiced or voiceless, stop or fricative (apart from intrinsic duration of the different vowels). The children's task was to produce a series of CVC English words using each of the vowels /I i u/ before one voiceless and one voiced fricative. Four stimulus conditions were used: 1) A visual stimulus, using familiar story-book pictures, and 2-4) three sets of tape recorded stimuli with the vowel /i/: one set had normal differential vowel duration, another had abnormal equal vowel duration, and the third had four occurrences of each word with graded vowel durations.

The children's responses were tape recorded in a sound-treated booth, and acoustic displays were made of their attempts to reproduce the stimulus words. Vowel duration measurements were made on duplex oscillograms; productions of the final consonants were transcribed by three linguists.

Results showed that acquisition of differential vowel duration preceded control of the voicing feature which conditions it in adult English. Since there were very few mistakes in manner of articulation of the final consonants it was not possible to determine whether its control preceded that of differential vowel duration. Correct intrinsic vowel duration was produced in all responses.

Some inferences were made from the results regarding development of differential vowel duration and control of voicing of final consonants. Variations in responses under the four types of stimuli used, and individual variations between one child whose parent evidenced distinct dialect differences (black dialect), and the other eight children (white dialect), permitted the positing of three stages in the acquisition of differential vowel duration in American English in relation to the voicing of final consonants. In the first stage, the child imitates the adult's differential vowel duration very well and produces it correctly regardless of the final consonant. He does not have control of voicing of final consonants in the majority of his CVC utterances. As the child gains control of final consonant voicing in the majority of his CVC utterances (second stage), voiced final consonants become associated with increased vowel duration. In this stage, a voiced final consonant would be his cue to produce a longer vowel, rather than direct imitation of the vowel. In the third stage, which may perhaps be simultaneous with the second, or occur later, the child makes the reverse association, increased vowel duration with voiced final consonants, which eventually permits increased vowel duration to act as a sufficient cue to the perception of voiced final consonants.

Chapter 1

INTRODUCTION

This study investigated the acquisition of differential vowel duration in American children from 21 months to 36 months of age. By differential vowel duration is meant the relatively different durations of vowels produced before different final consonants. In adult English the vowel durations differ as the final consonants differ in 1) voicing (voiceless or voiced)[1] and 2) manner of articulation (stop or fricative). This is also characteristic of certain other languages.[2] A number of phonetic studies of American English with adult speakers over the past twenty years have established that, other things being equal, a vowel is longer before a syllable-final voiced consonant than a voiceless consonant, and longer before a final fricative consonant than a stop consonant.[3] This differential duration associated with the voicing and manner of articulation of the following consonant is quite independent of the intrinsic duration characteristic of each vowel, also reported in these previous studies.

Since differential vowel duration for adults is predictable in terms of the phonological environment, it is appropriately treated as non-phonemic in the phonology of American English. This does not preclude the possibility, however, of its functioning as a phonemic feature at some stage in the development of a child learning English as his

first language. Nor does its non-phonemic status in adult English bear on the question of whether differential vowel duration is physiologically conditioned[4] (hence, possibly a phonetic universal), or learned[5] (hence, language specific). Pertinent to both of these points is information about the stages of language development in children learning American English as their first language, including specifically the relative order of acquisition of differential vowel duration versus the features which are said to condition it in adult English.

Child language development studies have shown that the first stage in the development of a child's phonological system comes with the consonant and vowel contrast.[6] Ninety-four percent of the utterances of children at 13 months of age consist of open syllables (CV or CVCV).[7] Studies on the development of the feature of voicing of consonants have shown that control of production of voiceless consonants precedes that for voiced consonants, and studies on the development of the feature of manner of articulation of consonants have shown that control of production of stops precedes that for fricatives.[8] Consonants are used only initially and medially in the English syllabic system during the first year of language acquisition, and it is not until the second year that they are actually produced finally.[9]

To date, there is very little known about the development in child language of non-phonemic features of adult language, such as differential vowel duration.[10] There are 2 instances mentioned in the literature, however, where vowel duration did function phonemically. Leopold (1939-49) writes that his daughter, Hildegard, at age 2, used vowel length to distinguish between "walk" [wɔk] and "fork" [wɔ:k]. Velten

(1943) reports that his daughter, Joan, at age 2, used vowel length to distinguish between "beat" /put/ and "bead" /pu:t/.

Given that children produce CV syllables from 13 months on, but not CVC syllables until possibly 24 months, and that control of voicing and manner of articulation of consonants is not simultaneous, it seemed likely that the CVC utterances of children in a longitudinal study from 21 to 36 months of age would give some insight into the acquisition process of differential vowel duration in relation to the features said to condition it in adult speech (voicing and manner of articulation of final consonants), especially if the latter were not fully controlled at the time of the acquisition of the former.

Since Jakobson's writings in 1941, the notion has been accepted that a child acquires his phonological system in a non-random, patterned way. I did not undertake a full phonemic analysis of the language system of each individual child, but rather looked in considerable detail at the acquisition process of differential vowel duration. Results should be relevant to studies of the patterning of language acquisition.

FOOTNOTES (Chapter 1)

1. Throughout the paper, the voicing opposition of consonant classes is labeled voiceless/voiced, although it has been referred to elsewhere as tense/lax (Jakobson et al., 1969; Chomsky and Halle, 1968) or fortis/lenis (Malécot, 1970). The voiceless/voiced label was chosen because it refers directly to the vibration of the vocal cords and the acoustic representation of this periodicity was very important in the identification of voiced consonants in acoustic displays of CVC words.
2. The presence of conditioned differential vowel duration in Spanish was reported by Zimmerman and Sapon, 1957, and criticized by Delattre, 1962. Vowel duration in English, German, Spanish and French was also discussed by Delattre, 1965.
3. An early study on the influence of final consonants on the duration of preceding vowels was reported by House and Fairbanks, 1953. Vowel duration before voiceless consonants was reported to be 66% of that before voiced consonants, summed across all vowels. Vowels were always relatively shorter before stops than before fricatives, but no fixed ratio was established.
4. The possibility of differential vowel duration being physiologically conditioned has been suggested by Stevens (personal communication, December 30, 1968).
5. The possibility of differential vowel duration in English being basically learned has been suggested by Lehiste (personal communication, December 14, 1968).

FOOTNOTES continued (Chapter 1)

6. This initial contrast of consonant versus vowel is a universal first stage in child language acquisition (Jakobson, 1941).

7. This was generally the case for children studied from 13 to 18 months of age, Winitz and Irwin, 1958.

8. This was shown for English by studies done by Irwin, 1947; Albright and Albright, 1956; Weir, 1962; Ervin and Miller, 1963; and Moskowitz, 1970. The same was reported for Russian by Shvachkin, 1948; and for Japanese as well as English, by Menyuk, 1968.

9. Studies on consonantal position in the early stages of child language development have been reported by Irwin, 1951 and 1958.

10. There have been some studies on the development of supra-segmentals in infant speech which indicate that stress and intonation are very important relatively early in the language acquisition process (Pike, 1949). Lewis (1951) speculates that intonational rather than phonetic form may dominate in a child's response, in a certain stage prior to his complete control of the phonetic form. Blasdell and Jensen (1970) have experimented with stress patterns in imitation tasks with 28 to 39 month old children and have found that they learned the stressed words faster. Duration was not controlled in these experiments, however, only fundamental frequency and amplitude. Stress and intonation patterns are carried by

FOOTNOTES continued (Chapter 1)

the fundamental frequency, amplitude and duration of the vocalic segments of speech. Thus, there is a good possibility that on the basis of results from these types of studies, one might predict good attentiveness to, and close production of, differential vowel duration at a very early stage in child language development.

Chapter 2

FIRST STUDY; VOWEL DURATION IN CHILDREN'S RESPONSES ELICITED WITH A PICTURE STORY

INTRODUCTION

This study investigated the development of production of correct differential vowel duration in utterances elicited with a picture story. The main question asked was the following: At what age does production of correct differential vowel duration emerge? A pilot study with 3 subjects showed that correct differential vowel duration was produced by children 36 months of age. To study the developmental process in depth, two groups of children were chosen for longitudinal study. The first group was recorded over 10 monthly sessions from approximately 26 to 36 months of age. The need for a second, younger, group of children became apparent when it was discovered that some development had already taken place prior to the age of 26 months. The second group was recorded over a 3-month period from approximately 22 to 24 months of age.

The study of longitudinal development was two-fold. It involved 1) the study of the development of control of manner and voicing of the final consonant in a CVC word, and 2) the study of the development of differential vowel duration in relation to 1). Since it was entirely possible that correct differential vowel duration could be produced regardless of the nature of, or even occurrence of, the final consonant,

all responses were examined closely, even those in which no final consonant was produced. I.e. the study sought to determine at what age children produce correctly 1) voicing of final stops, 2) voicing of final fricatives, and 3) manner of articulation of final stops and fricatives; and whether each of these precedes or follows production of correct differential vowel duration. The study also sought to determine at what age children produce correct differential intrinsic vowel duration. Evidence of control of differential vowel duration and the voicing and manner of articulation of final consonants is based on tape recordings of the children's speech which were analyzed acoustically; no physiological testing was done.

METHOD

STIMULUS MATERIALS

Because of the limit of a child's attention span, only 3 vowels were chosen for study. They represented the tense/lax contrast and the front/back contrast. The vowels chosen were the following: the close lax front vowel /I/, of short intrinsic duration, the close tense front vowel /i/ of medium intrinsic duration and the close tense back vowel /u/ also of medium intrinsic duration. For average intrinsic duration values see Table 1.

Twelve common C(C)VC words each containing a vowel followed by a voiceless stop consonant, a voiced stop consonant, a voiceless fricative consonant or a voiced fricative consonant were chosen. The words used were the following:

For the vowel /I/	For the vowel /i/	For the vowel /u/
/stIk/ "stick"	/fit/ "feet"	/but/ "boot"
/bIb/ "bib"	/sid/ "seed"	/fud/ "food"
/kIs/ "kiss"	/tiθ/ "teeth"	/gus/ "goose"
/hIz/ "his"	/piz/ "peas"	/ʃuz/ "shoes"

A short story entitled The Scary Goose Story utilizing the above words was written.[1] The order of the words followed the story line rather than any particular order of vowel duration. The format of the story required the subject to complete a sentence by saying the word which was pictured. For example, the first sentence was, "Here's George Brown, and on his foot he's wearing only one black...(boot)." There was a picture of a boy wearing only one black boot. Two versions of the story were written. In the first version of the story, which was

Table 1
Intrinsic vowel duration (msec) of selected vowels
in four studies of American English

	Close lax vowel /I/	Close tense vowel /i/	Close tense vowel /u/
House and Fairbanks, (1953), p. 111 10 speakers 12 CVC words	not studied	199	195
Peterson and Lehiste, (1960), p. 702 5 speakers 30 CVC words	161	207	235
House, (1961), p. 1176 3 speakers 14 CVC words	168	216	216
Naeser, (1970b), 8 speakers 16 CVC words	162	199	199
Mean	164	205	211

used with the first group of children, the word /hIz/ was used for the lax vowel /I/ followed by a voiced fricative. This possessive morpheme, however, caused some difficulty in eliciting responses from the children. Later, in the second version of the story, which was used with the second, younger group of children, the substantive morpheme /bIz/, a then new laundry product on the market, was substituted for /hIz/. See Appendix A for both versions of The Scary Goose Story. Several copies of the story were made so that each child had his own book.

SUBJECTS

Group 1

Criteria for accepting a child into this group were the following:

1. The child was approximately 25 months of age.
2. The child was at least at "the naming stage" in language development (i.e. he was able to name objects spontaneously).
3. No other language besides American English was spoken in the home.

Six children, 3 male (white), 3 female (white), were chosen for this 10 month study. Their mean age at the beginning of the study was 25.2 months. All of the male and one of the females had 1 or more older siblings. The children were from upper middle class families living in Madiosn, Wisconsin.

Group 2

Criteria for accepting a child into this group were the same as above except for the following:

1. The child was approximately 22 months of age.
2. The child was in the stage of phonological development where

he sometimes substituted voiceless final consonants for voiced final consonants.

Three children, 2 male (white), 1 female (black) were chosen for this 3-month study. One of the males and the female had 1 or more older siblings. The children were from upper middle class families living in Madison, Wisconsin. The parents of the white subjects were from the upper Midwest; the parents of the black subject were from Louisiana.

PROCEDURE

Each child practiced saying the words for the picture story with his parents at home. Then, a parent of each child accompanied him to the Department of Linguistics Phonetics Laboratory each month. During the monthly recording session, the child spontaneously uttered the words in the story as he read through it with his mother or the experimenter. Children in Group 1 read through the story twice each month for 10 months; those in Group 2 read through the story 4 times in each of the two recording sessions for that group. As each child was also taking part in a vowel duration study investigating utterances elicited with a stimulus tape, each recording session took from ½ to 1 hour. There were frequent play periods in between the actual recording periods, however, to keep the child happy and interested. Most recording sessions were in the early morning.

Recording was done in a sound-treated booth where the child, the mother and the experimenter sat at a table. An Altec microphone (Model 684 B) was used with a Shure microphone mixer (Model M68) for necessary amplification in recording. Recording was done at 7½ i.p.s. on 1½ mil 175 Tenzar Scotch magnetic recording tape on a Sony tape recorder (Model TC-777-4). For a schematic diagram of the recording procedure, see Fig. 1.

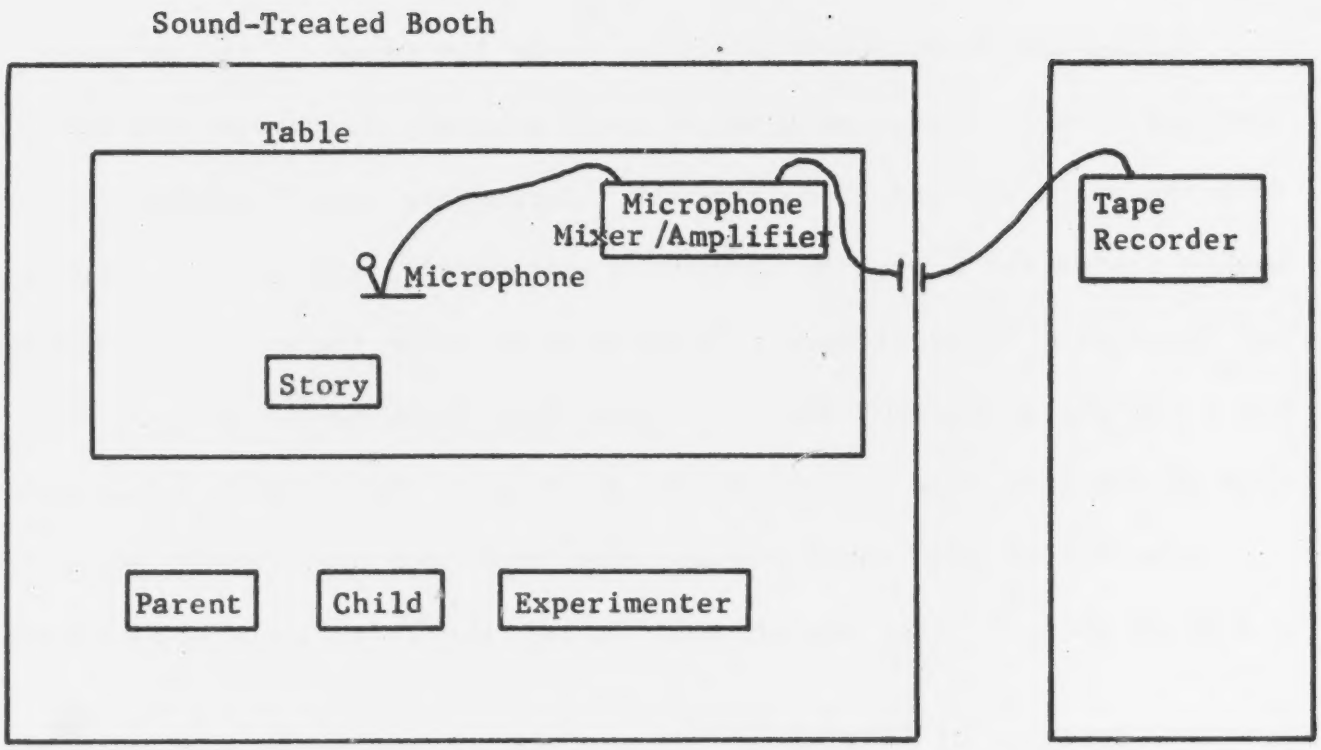

Fig. 1 Schematic diagram for recording utterances elicited with a picture story at the Department of Linguistics Phonetics Laboratory

During the first 5 months of the study for Group 1, it was found that any toys in the sound-treated booth severely distracted the child from the story and had to be removed. During the last 5 months, a toy monkey inside the booth was helpful in maintaining the child's attention and interest. Being allowed to play with it after the story was completed was a welcome reward for these children from 31-36 months of age. No toys of any kind were allowed in the booth with the children in Group 2.

A parent of each child was recorded under the same conditions over a 3-month period. Each parent read through the story twice each month.

Acoustic Analysis of Responses

Duplex oscillograms were produced for vowel duration measurements for the response utterances. For a detailed explanation of production and segmentation of duplex oscillograms, see Appendix B.

The duplex oscillograms were segmented and a first transcription of the response utterances was done by the author. Two transcription checks were then done by two other linguists.

Responses were not counted which were subjectively judged by the transcribers to be too loud or too soft. Also, responses were counted only when the child uttered the word for the picture by himself. If the mother or the experimenter had to say the word first, then the child repeated it, the response was not counted.

The vowel duration values for each response utterance were then coded for computer analysis of data reduction. The class of the final response consonant - voiceless stop, voiced stop, voiceless fricative, voiced fricative, voiceless affricate, voiced affricate, nasal, open

syllable - was coded with each vowel duration value.

RESULTS AND DISCUSSION

SCORING OF VOWEL DURATION DATA

The vowel durations produced by the children were scored in 5 ways. Mean vowel duration values were computed according to the stimulus consonant, the response consonant, and the correctness or incorrectness of the child's response consonant, in the following combinations:

All response consonants as a function of the stimulus

Scoring procedure type 1 used mean vowel duration values from the response utterances obtained for a given stimulus word, whether the final response consonant produced was correct or incorrect.[2]

Response consonants as a function of the response

Scoring procedure type 2 used mean vowel duration values only when the final response consonant produced was a voiceless stop, a voiced stop, a voiceless fricative, or a voiced fricative, whether it was a correct or an incorrect response.[3] Type 2 thus had both correct and incorrect responses counted as a function of the response consonant actually produced in the computation of mean vowel duration values.

All correct response consonants

Scoring procedure type 3 used mean vowel duration values only from response utterances where the final response consonant was produced correctly.[4]

Incorrect response consonants as a function of the stimulus

Scoring procedure type 4 used mean vowel duration values only from response utterances where the final response consonant was

produced incorrectly, regardless of the nature of the incorrect production, and the values were scored as a function of the stimulus consonant.[5]

Incorrect response consonants as a function of the response

Scoring procedure type 5 used mean vowel duration values computed from the incorrect response utterances in which the final response consonant was either a voiceless stop, a voiced stop, a voiceless fricative, or a voiced fricative (a subset of the incorrect responses in Type 4). These responses were then counted as a function of the response consonant in the computation of mean vowel duration values.[6]

Response utterances from the 9 children from the 2 groups in this longitudinal study were separated into 5 groupings based on age and recording session number, in the following way:

Recording Session No.	Mean Age (mo.)	No. of Children	Group No.
1	22	3	2
3	24	3	2
1-3	27	6	1
4-6	30	6	1
7-10	34	6	1

Responses for each child are listed with vowel durations and final response consonants produced in Appendix C.

DESCRIPTIVE ANALYSIS OF RESULTS

The ages at which the children correctly produced 1) voicing of final stops, 2) voicing of final fricatives and 3) manner of articulation of final stops and fricatives and the ages at which the children

produced correct differential vowel duration are given below. The development of correct intrinsic vowel duration is also discussed. Development of the differential vowel duration for each of the 3 vowels is treated separately because physiologically each is produced differently. As previously mentioned, they represent the tense/lax and front/back contrasts. It is important to know if differential vowel duration develops with the same pattern for all 3 vowels or if it appears later with the tense vowels or the back vowel than with the lax vowel or front vowels.

Vowel duration in relation to voicing of final stops

Final stops after /I/. Table 2 shows that the children produced the final voiceless stop (here /k/) with 0% error from the mean age of 22 months on. This table also shows, however, that with respect to voicing, the children at the mean age of 22 months produced the voiced stop (here /b/) with 50% error. The error rate here decreased with increasing age until 34 months where there was only a 2% error rate.

Scoring procedure type 1 on Table 3 and Fig. 2 shows, however, that despite the incorrect production of final voiced stops, correct differential vowel duration was produced continuously from the mean age of 22 months, when vowel duration before voiceless stops was 49% of that before voiced stops. At the mean age of 34 months, vowel duration before voiceless stops was 63% of that before voiced stops. The same pattern was also seen in scoring procedure types 2 and 3.

The actual response consonants which were substituted for the stimulus voiced stop /b/ are shown in Table 2. Throughout all age groups,

Table 2
First study, children's responses to picture stimuli.
Incorrect response consonants and missing responses
for /I/, /i/, /u/ before stops

Sess. No.	Mean Age (mo.)		/stIk/ V1.st.	/bIb/ Vd.st.	/fit/ V1.st.	/sid/ Vd.st.	/but/ V1.st.	/fud/ Vd.st.
1	22	Inc. resp. cons.	0	6/p/	1/ts/	6/t/	0	6/t/
		No. inc. resps.	0	6	1	6	0	6
		% inc. resps.	0%	50%	8%	50%	0%	50%
		No. missing resps.	0	1	0	0	0	0
		% missing resps.	0%	8%	0%	0%	0%	0%
3	24	Inc. resp. cons.	0	4/p/	0	4/t/	0	4/t/
		No. inc. resps.	0	4	0	4	0	4
		% inc. resps.	0%	33%	0%	33%	0%	33%
		No. missing resps.	0	0	0	0	0	0
		% missing resps.	0%	0%	0%	0%	0%	0%
1-3	27	Inc. resp. cons.	0	9/p/ 2/m/ 1/t/	3/ts/ 1/d/	7/t/ 1/dz/ 1/Ø/	0	8/t/ 2/n/ 1/dz/
		No. inc. resps.	0	12	4	9	0	11
		% inc. resps.	0%	33%	11%	25%	0%	30%
		No. missing resps.	5	4	7	5	5	6
		% missing resps.	13%	11%	19%	13%	13%	16%
4-6	30	Inc. resp. cons.	0	3/p/ 2/m/	3/ts/	4/t/ 1/ts/ 1/Ø/	0	1/t/
		No. inc. resps.	0	5	3	6	0	1
		% inc. resps.	0%	13%	8%	16%	0%	2%
		No. missing resps.	0	2	2	2	3	2
		% missing resps.	8%	5%	5%	5%	8%	5%
7-10	34	Inc. resp. cons.	0	4/p/ 1/m/	1/ts/	1/t/	0	3/t/
		No. inc. resps.	0	5	1	1	0	3
		% inc. resps.	0%	2%	2%	2%	0%	6%
		No. missing resps.	10	8	9	11	10	9
		% missing resps.	20%	16%	18%	22%	20%	18%

Table 3

First study, children's responses to picture stimuli. Mean vowel duration (msec) and duration ratio for /I/ before stops in /stIk/, /bIb/, as a function of children's age.

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
1	7	24	144	275	.52	144	275	.52	144	275	.52	---	---	---	---
1	8	21	160	281	.57	220	---	---	160	---	---	---	281	281	---
1	9	21	92	238	.39	133	262	.51	92	262	.35	---	215	215	---
1	Mean	22	132	265	.49	166	268	.61	132	268	.49	---	248	248	---
3	7	26	182	235	.78	182	235	.78	182	235	.78	---	---	---	---
3	8	23	205	340	.60	272	---	---	205	---	---	---	340	340	---
3	9	23	95	218	.43	95	218	.43	95	218	.43	---	---	---	---
3	Mean	24	160	264	.60	183	226	.80	160	226	.70	---	340	340	---
1-3	1	27.6	162	342	.47	188	448	.41	162	448	.36	---	290	322	---
1-3	2	28.5	151	310	.48	151	310	.48	151	310	.48	---	---	---	---
1-3	3	25	136	418	.32	136	418	.32	136	418	.32	---	---	---	---
1-3	4	25.6	110	222	.49	166	---	---	110	---	---	---	222	222	---
1-3	5	27.6	195	199	.97	186	161	115	195	161	121	---	275	275	---
1-3	6	28	170	252	.67	170	252	.67	170	252	.67	---	---	---	---
1-3	Mean	27	154	290	.53	166	318	.52	154	318	.48	---	262	273	---
4-6	1	31.5	135	188	.71	135	188	.71	135	188	.71	---	---	---	---
4-6	2	31	153	224	.68	153	224	.68	153	224	.68	---	---	---	---
4-6	3	29	110	190	.57	110	190	.57	110	190	.57	---	---	---	---
4-6	4	29	140	269	.52	173	310	.55	140	310	.45	---	234	234	---
4-6	5	31.5	203	276	.73	203	276	.73	203	276	.73	---	---	---	---
4-6	6	31	138	226	.61	139	259	.53	139	259	.53	---	---	---	---
4-6	Mean	30.2	146	228	.64	152	241	.63	146	241	.60	---	234	234	---
7-10	1	34.5	135	298	.45	140	326	.42	135	326	.41	---	190	212	---
7-10	2	34.5	136	174	.78	136	174	.78	136	174	.78	---	---	---	---
7-10	3	32.5	114	242	.47	114	256	.44	114	256	.44	---	215	---	---
7-10	4	31.5	231	298	.77	231	298	.77	231	298	.77	---	---	---	---
7-10	5	34.5	244	355	.68	260	346	.75	244	346	.70	---	380	380	---
7-10	6	34.5	100	168	.59	100	168	.59	100	168	.59	---	---	---	---
7-10	Mn.	33.9	160	256	.63	164	261	.62	160	261	.61	---	262	296	---
	Parent No.														
1-3	7								142	257	.55				
1-3	8								178	334	.53				
1-3	9								187	238	.78				
1-3	1								124	198	.62				
1-3	2								108	195	.56				
1-3	3								122	162	.75				
1-3	4								112	212	.53				
1-3	5								108	176	.62				
1-3	6								114	216	.53				
1-3	Mean								132	220	.60				

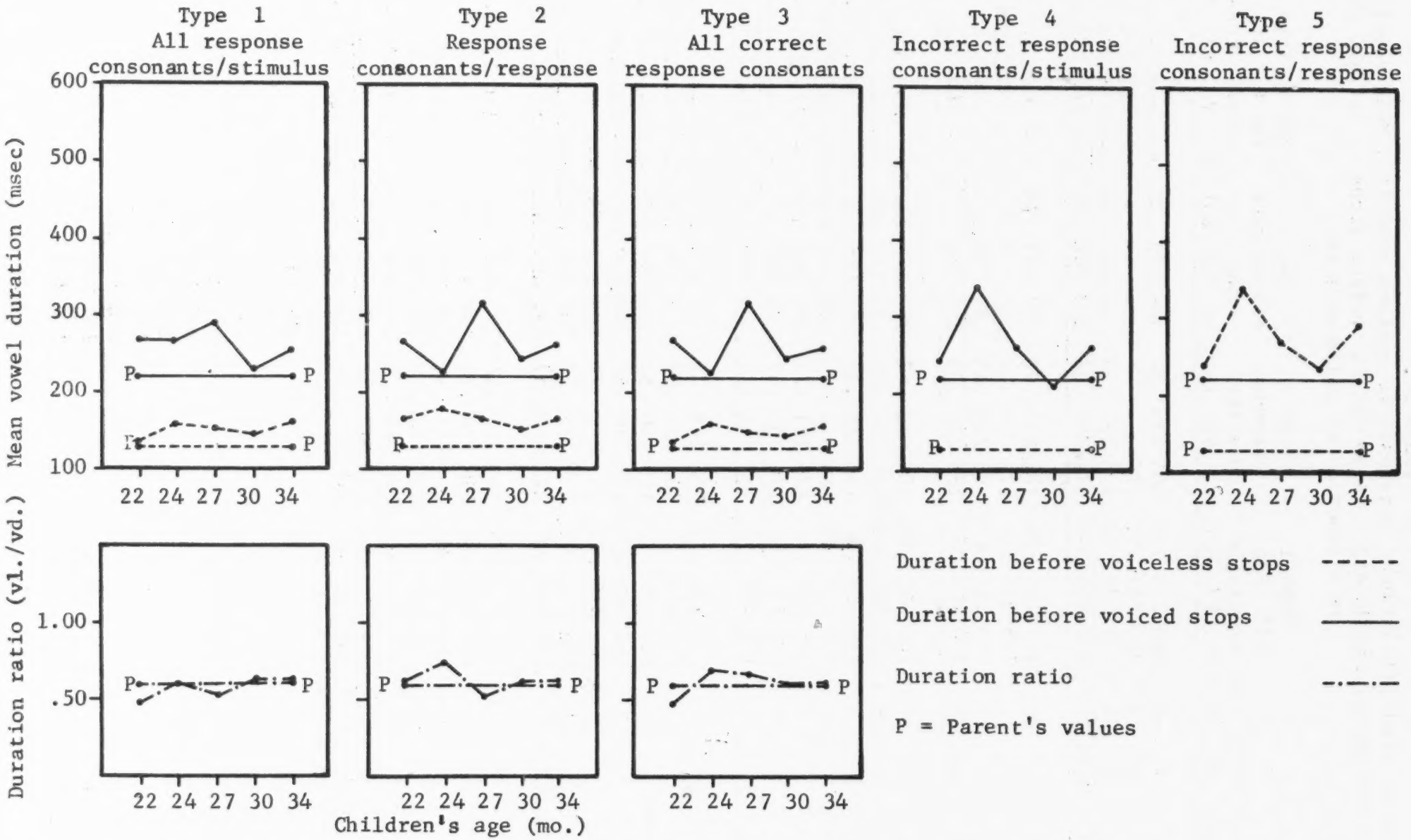

Fig. 2 First study, children's responses to picture stimuli. Mean vowel duration and duration ratio for /I/ before stops in /stIk/, /bIb/, as a function of children's age.

the most common substitution was the voiceless stop /p/ with 26 occurrences, then /m/ with 5 occurrences.[7]

Scoring procedure type 4 on Table 3 and Fig. 2 shows mean vowel duration before all the consonants which were used incorrectly for the stimulus voiced stop /b/. At 22 months the mean vowel duration before response consonants substituted incorrectly for /b/ (Type 4) was 248 msec (all following durations are given in msec) and the mean vowel duration before voiced stops produced correctly (Type 3) was 268. This is only a 20 msec difference. (The mean vowel duration before voiceless stops produced correctly was 132, a 116 msec difference.) Thus, Type 4 showed that the voiceless stops which were substituted for the voiced stop /b/, at 22 months, were used with correct increased vowel duration appropriate for the stimulus consonant, not the final response consonant. The same pattern was true for the other age groups. These findings are further substantiated by scoring procedure type 5.

Type 5, on Table 3 and Fig. 2, shows the mean vowel duration for the incorrectly used response consonants. At 22 months, the mean vowel duration before the incorrectly used voiceless stops (Type 5) was 248 (here, the same as Type 4) and the mean vowel duration before the correctly used voiceless stops (Type 3) was 132. This 116 msec difference shows that the children did not produce the correct increased vowel duration appropriate for the final response consonant, but rather they produced the correct increased vowel duration for the original stimulus consonant.

Fig. 3 compares the mean vowel durations for /I/ before correctly used voiceless and voiced stops (Type 3), with mean vowel durations

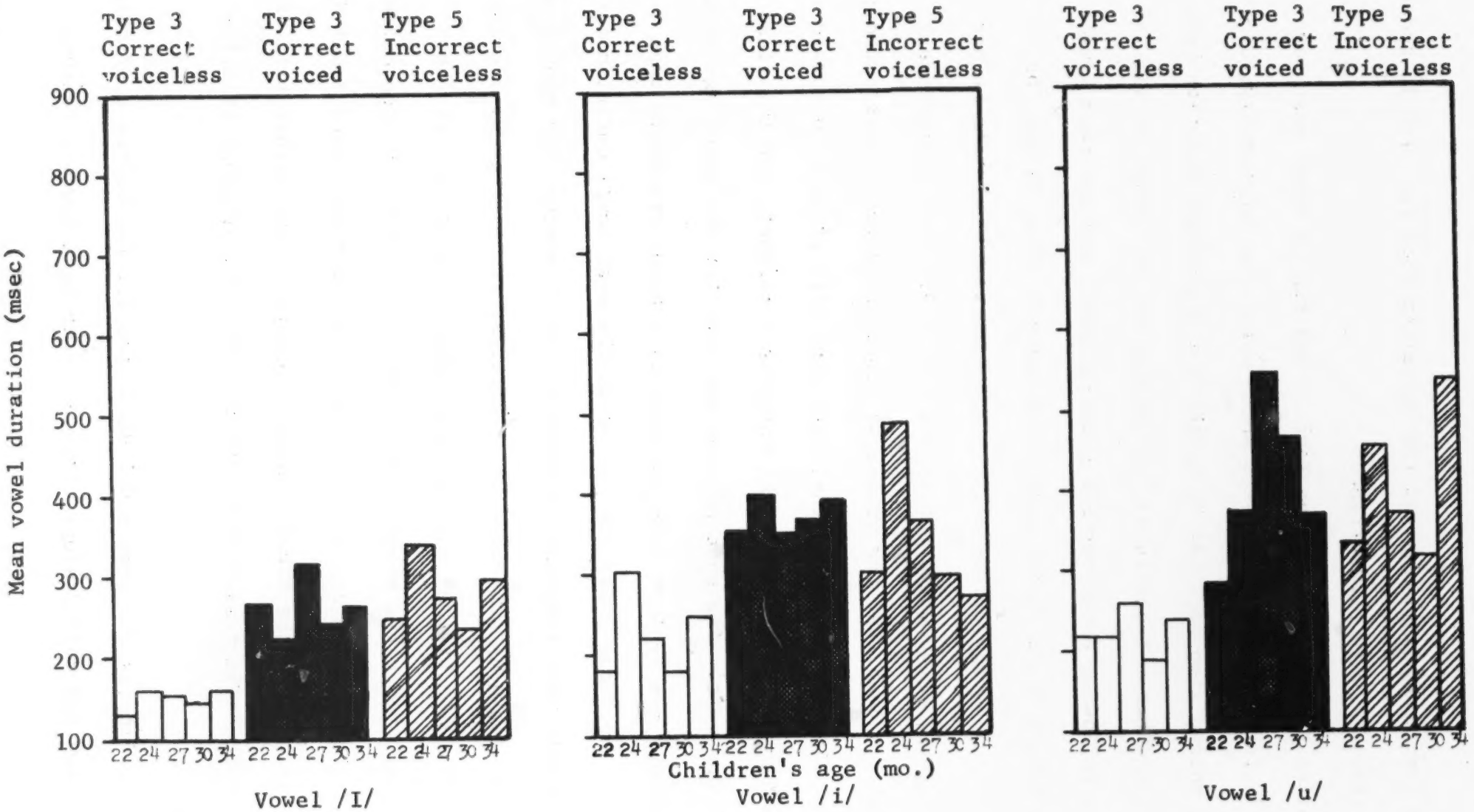

Fig. 3 First study, mean vowel duration for /I/, /i/, /u/ before correctly used voiceless and voiced stops and before voiceless stops substituted for voiced stops, as a function of children's age.

before voiceless stops substituted for the voiced stop /b/ (Type 5). This graph shows clearly that for all age groups the vowels produced with voiceless stops which were substituted for the voiced stop were much closer in mean duration to those used with the correctly produced voiced stops than to those used with the correctly produced voiceless stops. Thus, in summary, for the vowel /I/ before final stops, the vowel duration was usually appropriate for the final stimulus consonant regardless of the nature of the final response consonant.

Scoring procedure types 4 and 5 will not be discussed in detail in this chapter for the remaining vowels in the remaining consonant environments because the same general pattern which occurred with the vowel /I/ before stops repeats itself with /i/ and /u/ before stops as well as fricatives. A detailed discussion of the vowel durations produced with incorrect consonant substitutions (Types 4 and 5) is in Appendix D.

Final stops after /i/. Table 2 shows that regarding production of the final voiceless stop (here /t/) there were error rates which ranged from 11% at 27 months to 2% at 34 months. A similar decreasing error rate was seen for the voiced stop (/d/) with 50% error at 22 months and 2% at 34 months.

Scoring procedure type 1 on Table 4 and Fig. 4 shows, however, that despite the incorrect production of some of the final stops, correct differential vowel duration was produced continuously from the mean age of 22 months, where vowel duration before voiceless stops was 52% of that before voiced stops. At 34 months the vowel duration before voiceless stops was 63% of that before voiced stops. The same pattern was

Table 4

First study, children's responses to picture stimuli. Mean vowel duration (msec) and duration ratio for /i/ before stops in /fit/, /sid/, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
1	7	24	195	388	.50	195	388	.50	195	388	.50	---	---	---	---
1	8	21	215	338	.64	262	---	---	215	---	---	---	338	286	---
1	9	21	128	315	.41	204	322	.63	135	322	.42	110	308	308	---
1	Mean	22	180	346	.52	220	355	.61	182	355	.50	110	322	297	---
3	7	26	208	308	.67	208	308	.67	208	308	.67	---	---	---	---
3	8	23	508	588	.87	496	---	---	508	---	---	---	588	489	---
3	9	23	201	496	.41	201	496	.41	201	496	.41	---	---	---	---
3	Mean	24	306	464	.65	302	402	.74	306	402	.76	---	588	489	---
1-3	1	27.6	248	338	.73	248	355	.69	248	355	.69	---	435	---	---
1-3	2	28.5	258	491	.52	---	462	---	---	532	---	258	475	---	---
1-3	3	25	192	348	.55	192	348	.55	192	348	.55	---	---	---	---
1-3	4	25.6	250	310	.80	256	325	.78	250	325	.76	---	328	318	---
1-3	5	27.6	274	414	.66	308	318	.96	274	318	.86	---	462	410	---
1-3	6	28	222	326	.68	218	326	.66	138	226	.61	210	---	---	---
1-3	Mean	27	240	371	.64	244	356	.68	220	350	.62	234	425	364	---
4-6	1	31.5	155	275	.56	208	315	.66	140	315	.44	166	270	248	---
4-6	2	31	158	284	.55	158	284	.55	158	284	.55	---	---	---	---
4-6	3	29	176	662	.26	176	559	.31	176	559	.31	---1210		---	---
4-6	4	29	250	310	.80	283	328	.72	268	328	.81	---	442	344	---
4-6	5	31.5	186	265	.70	185	265	.69	186	265	.70	---	---	---	---
4-6	6	31	222	326	.68	152	455	.33	152	455	.33	---	---	---	---
4-6	Mean	30.2	191	354	.53	194	368	.52	180	368	.48	166	640	296	---
7-10	1	34.5	245	390	.62	204	390	.52	204	390	.52	470	---	---	---
7-10	2	34.5	258	491	.52	158	271	.58	158	271	.58	---	---	---	---
7-10	3	32.5	172	460	.37	180	481	.37	172	481	.35	---	270	270	---
7-10	4	31.5	296	364	.81	296	364	.81	296	364	.81	---	---	---	---
7-10	5	34.5	336	434	.77	336	434	.77	336	434	.77	---	---	---	---
7-10	6	34.5	308	408	.75	308	408	.75	308	408	.75	---	---	---	---
7-10	Mn.	33.9	269	424	.63	247	391	.63	246	391	.62	470	270	270	---
	Parent No.														
1-3	7								190	392	.51				
1-3	8								230	448	.51				
1-3	9								203	312	.65				
1-3	1								159	219	.73				
1-3	2								174	295	.59				
1-3	3								162	232	.70				
1-3	4								202	325	.62				
1-3	5								160	226	.71				
1-3	6								166	312	.54				
1-3	Mean								182	306	.59				

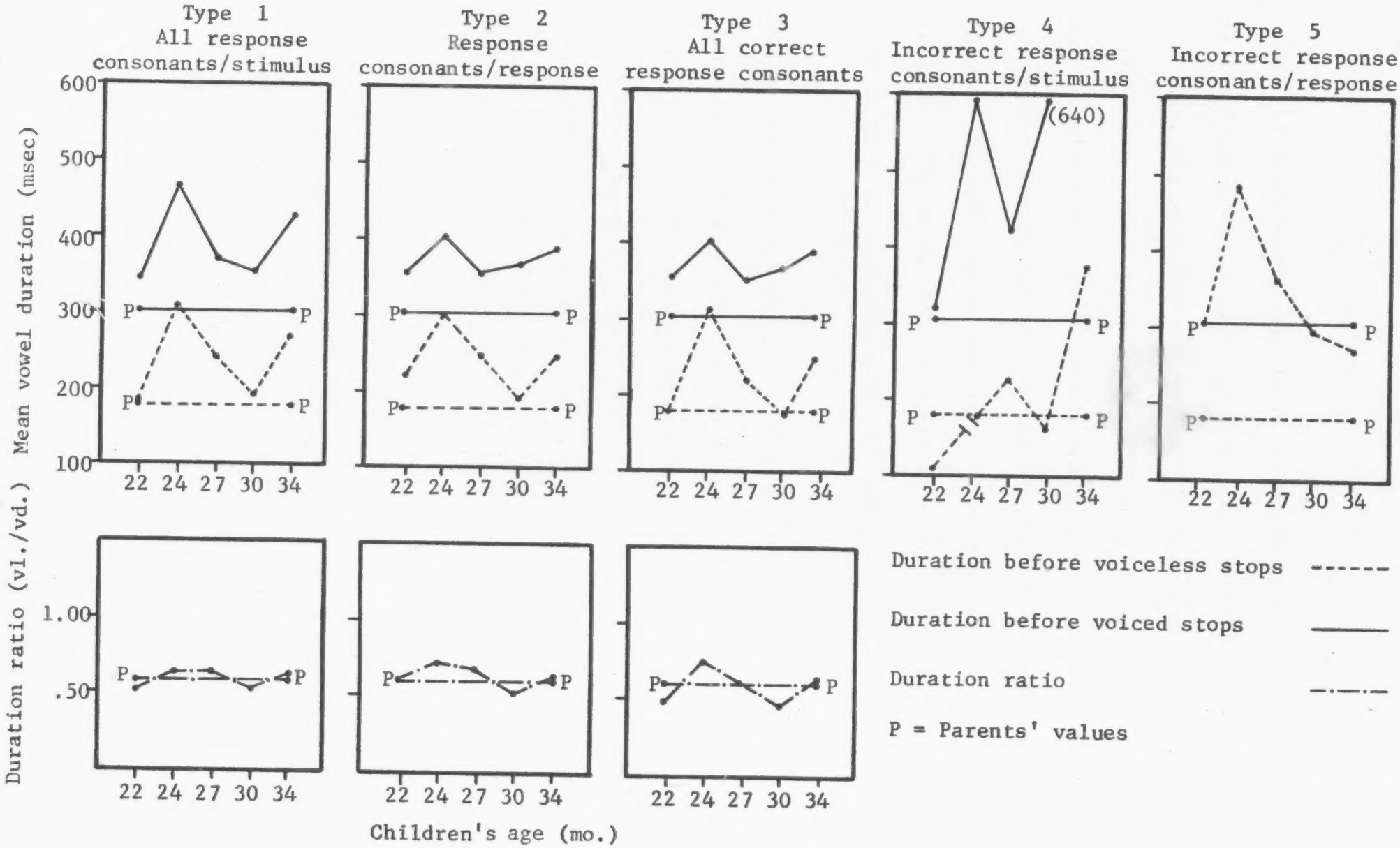

Fig. 4 First study, children's responses to picture stimuli. Mean vowel duration and duration ratio for /i/ before stops in /fit/, /sid/, as a function of children's age.

also seen in Types 2 and 3.

The actual response consonants which were substituted for the stimulus voiceless stop /t/ are shown in Table 2. Throughout all age groups, the most common substitution was the voiceless affricate /ts/ with 8 occurrences. This is probably because of the morphological (plural) irregularity in the stimulus word, /fit/. The affricate /ts/ substitutions for the stop /t/ formed the regular plural form in English.

The response consonants which were substituted for the stimulus voiced stop /d/ are also shown in Table 2. Throughout all age groups, the most common substitution was the voiceless stop /t/ with 22 occurrences.

Scoring procedure types 4 and 5 for /i/ before stops are listed in Table 4 and displayed in Fig. 4. They are discussed in detail in Appendix D. Fig. 3 shows that vowels before voiceless stops incorrectly substituted for the voiced stop /d/ were closer in duration to those before correctly used voiced stops, than to those before correctly used voiceless stops. Thus, vowel duration for /i/ before incorrectly substituted final response consonants was usually closer to the expected vowel duration before the stimulus consonant than to that before the incorrect response consonants.

Final stops after /u/. Table 2 shows that children produced the voiceless stop (/t/) with 0% error from the mean age of 22 months on. This table also shows, however, that at 22 months, they produced the final voiced stop (/d/) with 5% error; at 24 months, 33% and then finally a low 6% error rate again at 34 months.

Scoring procedure type 1 on Table 5 and Fig. 5 shows, however, that despite the incorrect production of the final voiced stops, correct differential vowel duration was produced continuously from the mean age of 22 months at which time the vowel duration before voiceless stops was 70% of that before voiced stops. At 34 months vowel duration before voiceless stops was 61% of that before voiced stops. The same pattern was also seen in Types 2 and 3.

The actual response consonants which were substituted for the stimulus voiced stop /d/ are shown in Table 2. Throughout all age groups, the most common substitution was the voiceless stop /t/ with 22 occurrences.

Scoring procedure types 4 and 5 are listed in Table 5 and displayed in Fig. 5. They are discussed in detail in Appendix D. Fig. 3 shows that the mean vowel duration before voiceless stops incorrectly substituted for the voiced stop /d/ was closer to the duration before the correctly used voiceless stops. Thus, vowel duration for /u/ before incorrectly substituted final response consonants was usually closer to the expected vowel duration before the stimulus consonant than the incorrectly substituted response consonant.

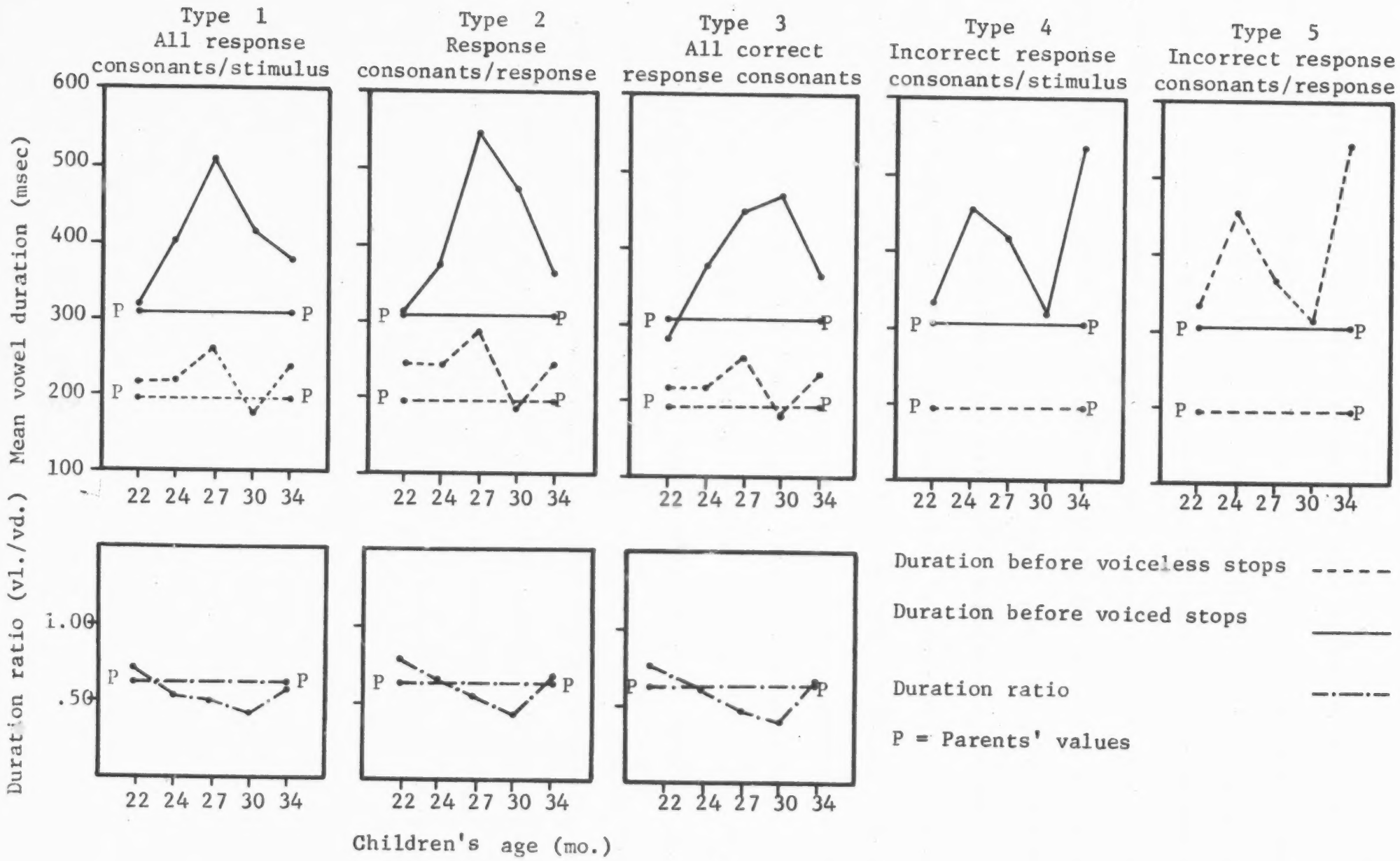

Fig. 5 First study, children's responses to picture stimuli. Mean vowel duration and duration ratio for /u/ before stops in /but/, /fud/, as a function of children's age.

Table 5

First study, children's responses to picture stimuli. Mean vowel duration (msec) and duration ratio for /u/ before stops in /but/, /fud/, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
1	7	24	202	315	.64	238	293	.81	202	293	.69	---	380	380	---
1	8	21	272	313	.87	290	370	.78	272	---	---	---	313	313	370
1	9	21	170	292	.58	218	272	.80	170	272	.62	---	312	312	---
1	Mean	22	215	306	.70	248	312	.79	215	282	.76	---	335	335	370
3	7	26	186	280	.67	186	280	.67	186	280	.67	---	---	---	---
3	8	23	311	455	.68	383	---	---	311	---	---	---	455	455	---
3	9	23	158	468	.34	158	468	.34	158	468	.34	---	---	---	---
3	Mean	24	218	400	.54	242	374	.64	218	374	.58	---	455	455	---
1-3	1	27.6	253	505	.50	263	722	.36	253	722	.35	---	396	410	---
1-3	2	28.5	234	415	.56	234	398	.58	234	398	.58	---	320	---	---
1-3	3	25	312	680	.45	313	680	.46	312	680	.45	---	---	135	---
1-3	4	25.6	184	594	.30	327	630	.51	184	630	.29	---	532	532	---
1-3	5	27.6	299	408	.73	324	390	.83	299	390	.76	---	412	412	---
1-3	6	28	273	450	.60	273	450	.60	273	450	.60	---	---	---	---
1-3	Mean	27	259	508	.50	289	545	.53	259	545	.47	---	415	372	---
4-6	1	31.5	181	410	.44	181	410	.44	181	410	.44	---	---	---	---
4-6	2	31	165	350	.47	165	350	.47	165	350	.47	---	---	---	---
4-6	3	29	148	505	.29	148	505	.29	148	505	.29	---	---	---	---
4-6	4	29	189	594	.31	189	594	.31	189	594	.31	---	---	---	---
4-6	5	31.5	240	390	.61	240	390	.61	240	390	.61	---	---	---	---
4-6	6	31	138	226	.61	230	542	.42	204	542	.37	---	315	315	---
4-6	Mean	30.2	176	412	.42	192	465	.43	188	465	.40	---	315	315	---
7-10	1	34.5	279	436	.63	326	333	.97	279	333	.83	---	742	742	---
7-10	2	34.5	140	271	.52	140	271	.51	140	271	.51	---	---	---	---
7-10	3	32.5	164	426	.38	164	426	.38	164	426	.38	---	---	---	---
7-10	4	31.5	384	502	.76	384	502	.76	384	502	.76	---	---	---	---
7-10	5	34.5	310	433	.71	313	435	.71	310	435	.71	---	335	335	---
7-10	6	34.5	138	226	.61	138	226	.61	138	226	.61	---	---	---	---
7-10	Mn.	33.9	236	382	.61	244	366	.66	236	366	.64	---	538	538	---
	Parent No.														
1-3	7								209	401	.53				
1-3	8								239	409	.58				
1-3	9								200	282	.71				
1-3	1								183	252	.75				
1-3	2								184	296	.62				
1-3	3								160	265	.61				
1-3	4								205	312	.66				
1-3	5								178	228	.78				
1-3	6								193	323	.60				
1-3	Mean								194	308	.62				

Vowel duration in relation to final fricatives

Final fricatives after /I/. Table 6 shows that children at 22 and 24 months produced the final voiceless fricative (/s/) with no errors. There was a 5% error rate at the mean age of 27 months, then no errors again at 30 and 34 months. This table also shows that at 22 months, the children produced the final voiced fricative (/z/) with 33% error and there was a decreasing error rate until 34 months when there were no errors.

Scoring procedure type 1 on Table 7 and Fig. 6 shows, however, that despite the incorrect production of some of the final fricatives, correct differential vowel duration was produced continuously from the mean age of 22 months, at which time vowel duration before voiceless fricatives was 50% of that before voiced fricatives. At the mean age of 34 months, the vowel duration before voiceless fricatives was 67% of that before voiced fricatives. The same pattern was also seen in Types 2 and 3.

The actual response consonants which were substituted for the stimulus voiceless fricative /s/ are listed in Table 6. There was one instance of the voiced fricative /ð/ and one instance of an open syllable.

The response consonants which were substituted for the stimulus voiced fricative /z/ are shown in Table 6. Throughout all age groups, the most common substitutions were the voiceless fricative /s/ with 20 occurrences, and the voiceless affricate /ts/ with 3 occurrences.

Scoring procedure types 4 and 5 are listed in Table 7 and displayed in Fig. 6. They are discussed in detail in Appendix D. Fig. 7 shows that the mean vowel durations before voiceless fricatives incorrectly substituted for the voiced fricative /z/ were closer to those before the

Table 6
First study, children's responses to picture stimuli.
Incorrect response consonants and missing responses
for /I/, /i/, /u/ before fricatives

Sess. No.	Mean Age(mo.)		/kIs/ Vl.fr.	/hIz/ /bIz/ Vd.fr.	/tiθ/ Vl.fr.	/piz/ Vd.fr.	/gus/ Vl.fr.	/ʃuz/ Vd.fr.
1	22	Inc. resp. cons.	0	4/s/	4/t/	5/s/ 1/ts/	0	2 /s/ 1/ts/ 1/bus/
		No. inc. resp.	0	4	4	6	0	4
		% inc. resp.	0%	33%	33%	41%	0%	33%
		No. missing resp.	0	0	0	2	0	0
		% missing resps.	0%	0%	0%	16%	0%	0%
3	24	Inc. resp. cons.	0	4/s/	4/t/	4/s/ 1/θs/	0	1/s/
		No. inc. resp.	0	4	4	5	0	1
		% inc. resp.	0%	33%	33%	41%	0%	8%
		No. missing resp.	0	0	0	0	0	0
		% missing resps.	0%	0%	0%	0%	0%	0%
1-3	27	Inc. resp. cons.	1/ / 1/Ø/	7/s/ 2/ts/	4/t/ 2/Ø/ 1/ts/	3/s/ 3/ts/ 2/dz/ 2/Ø/ 1/t/	5/ts/ 2/Ø/ 1/?/	8/Ø/ 4/s/ 1/h/
		No. inc. resp.	2	9	7	11	8	13
		% inc. resp.	5%	25%	19%	30%	22%	36%
		No. missing resp.	6	10	5	4	6	6
		% missing resps.	16%	27%	13%	11%	16%	16%
4-6	30	Inc. resp. cons.	0	5/s/ 1/dz/ 1/ts/	2/t/	3/Ø/ 1/s/	1/ts/	2/Ø/
		No. inc. resp.	0	7	2	4	1	2
		% inc. resp.	0%	19%	5%	11%	2%	5%
		No. missing resp.	3	2	2	2	2	4
		% missing resps.	8%	5%	5%	5%	5%	11%
7-10	34	Inc. resp. cons.	0	0	0	1/s/ 1/Ø/	0	2/Ø/ 2/dz/
		No. inc. resp.	0	0	0	2	0	4
		% inc. resp.	0%	0%	0%	4%	0%	8%
		No. missing resp.	9	8	9	9	9	10
		% missing resps.	18%	16%	18%	18%	18%	20%

Table 7

First study, children's responses to picture stimuli. Mean vowel duration (msec) and duration ratio for /I/ before fricatives in /kIs/, /hIz/, or /bIz/, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim V1.	Vd.	Rat.	Type 2 Response cons/resp V1.	Vd.	Rat.	Type 3 All correct resp cons V1.	Vd.	Rat.	Type 4 Inc R cons/S V1.	Vd.	Type 5 Inc R cons/R V1.	Vd.
1	7	24	194	371	.52	194	371	.52	194	371	.52	---	---	---	---
1	8	21	246	542	.45	394	---	---	246	---	---	---	542	542	---
1	9	21	212	380	.56	212	380	.56	212	380	.56	---	---	---	---
1	Mean	22	218	431	.50	266	376	.70	218	376	.57	---	542	542	---
3	7	26	148	302	.49	148	302	.49	148	302	.49	---	---	---	---
3	8	23	292	460	.63	376	---	---	292	---	---	---	460	460	---
3	9	23	216	381	.56	216	299	.72	216	381	.56	---	---	---	---
3	Mean	24	218	381	.57	246	300	.82	218	342	.63	---	460	460	---
1-3	1	27.6	309	498	.62	309	498	.62	309	498	.62	---	---	---	---
1-3	2	28.5	300	350	.85	300	376	.79	300	376	.79	---	300	300	---
1-3	3	25	552	408	1.35	105	504	.20	105	408	.25	1000	---	---	1215
1-3	4	25.6	214	326	.65	250	---	---	214	---	---	---	326	315	---
1-3	5	27.6	230	304	.75	232	335	.69	230	335	.68	---	272	272	---
1-3	6	28	243	314	.77	243	314	.77	243	314	.77	---	---	---	---
1-3	Mean	27	308	367	.83	240	405	.59	234	386	.60	1000	299	296	1215
4-6	1	31.5	231	408	.56	231	408	.56	231	408	.56	---	---	---	---
4-6	2	31	180	262	.68	180	262	.68	180	262	.68	---	---	---	---
4-6	3	29	180	434	.41	180	434	.41	180	434	.41	---	---	---	---
4-6	4	29	268	208	1.28	250	205	1.21	268	205	1.30	---	222	222	---
4-6	5	31.5	250	376	.56	250	398	.62	250	398	.62	---	330	---	---
4-6	6	31	238	432	.55	229	366	.62	229	366	.62	---	---	---	---
4-6	Mean	30.2	224	353	.63	220	346	.63	223	346	.64	---	276	222	---
7-10	1	34.5	245	508	.48	245	508	.48	245	508	.48	---	---	---	---
7-10	2	34.5	196	240	.81	196	240	.81	196	240	.81	---	---	---	---
7-10	3	32.5	171	346	.49	171	346	.49	171	346	.49	---	---	---	---
7-10	4	31.5	328	388	.84	328	388	.84	328	388	.84	---	---	---	---
7-10	5	34.5	368	480	.76	368	480	.76	368	480	.76	---	---	---	---
7-10	6	34.5	201	384	.52	201	384	.52	201	384	.52	---	---	---	---
7-10	Mn.	33.9	252	391	.67	252	391	.64	252	391	.64	---	---	---	---
	Parent No.														
1-3	7								202	524	.39				
1-3	8								225	488	.46				
1-3	9								216	419	.52				
1-3	1								168	306	.54				
1-3	2								162	352	.64				
1-3	3								143	270	.54				
1-3	4								172	372	.46				
1-3	5								139	282	.49				
1-3	6								136	346	.40				
1-3	Mean								174	373	.46				

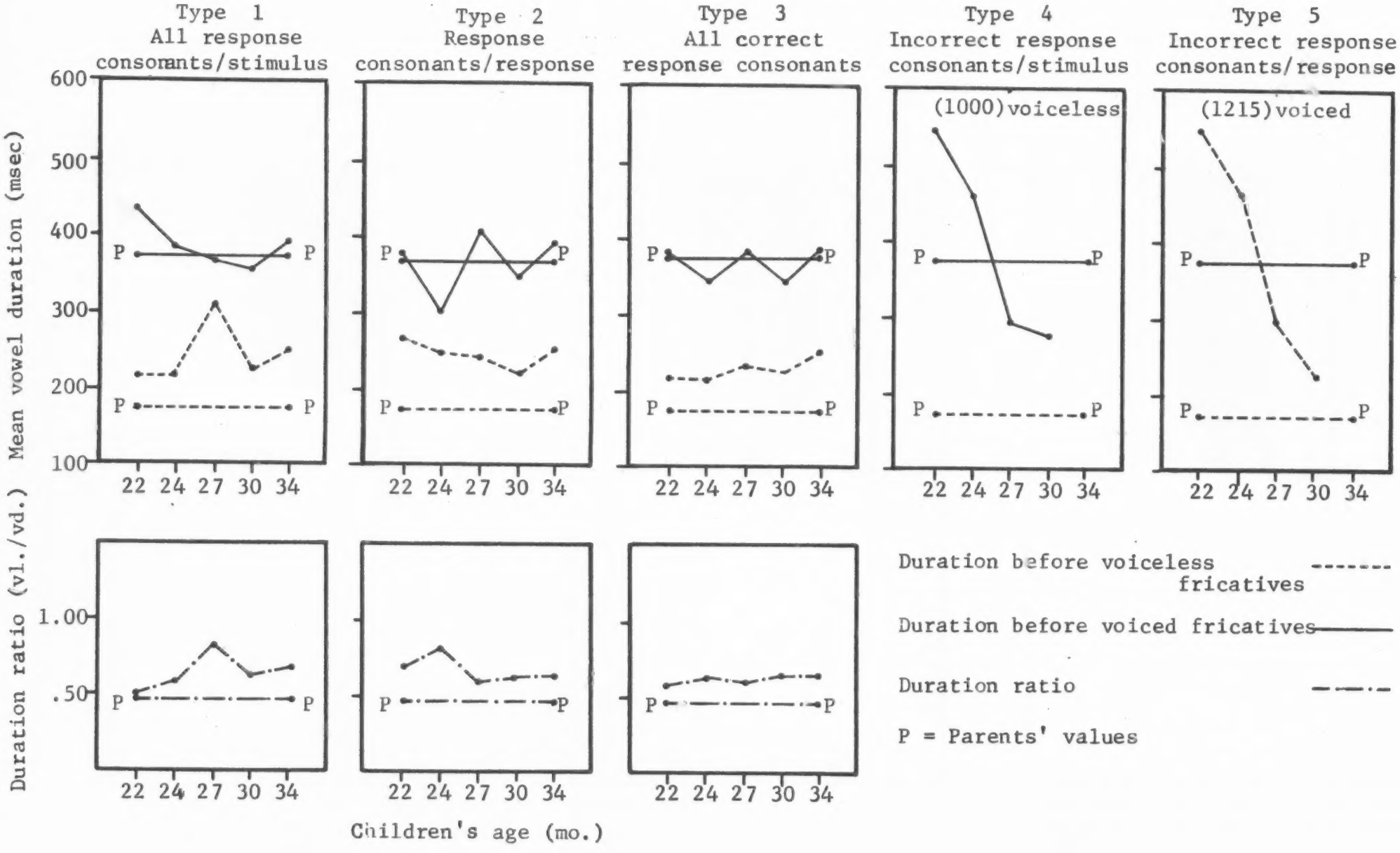

Fig. 6 First study, children's responses to picture stimuli. Mean vowel duration and duration ratio for /I/ before fricatives in /kIS/, /hIz bIz/, as a function of children's age.

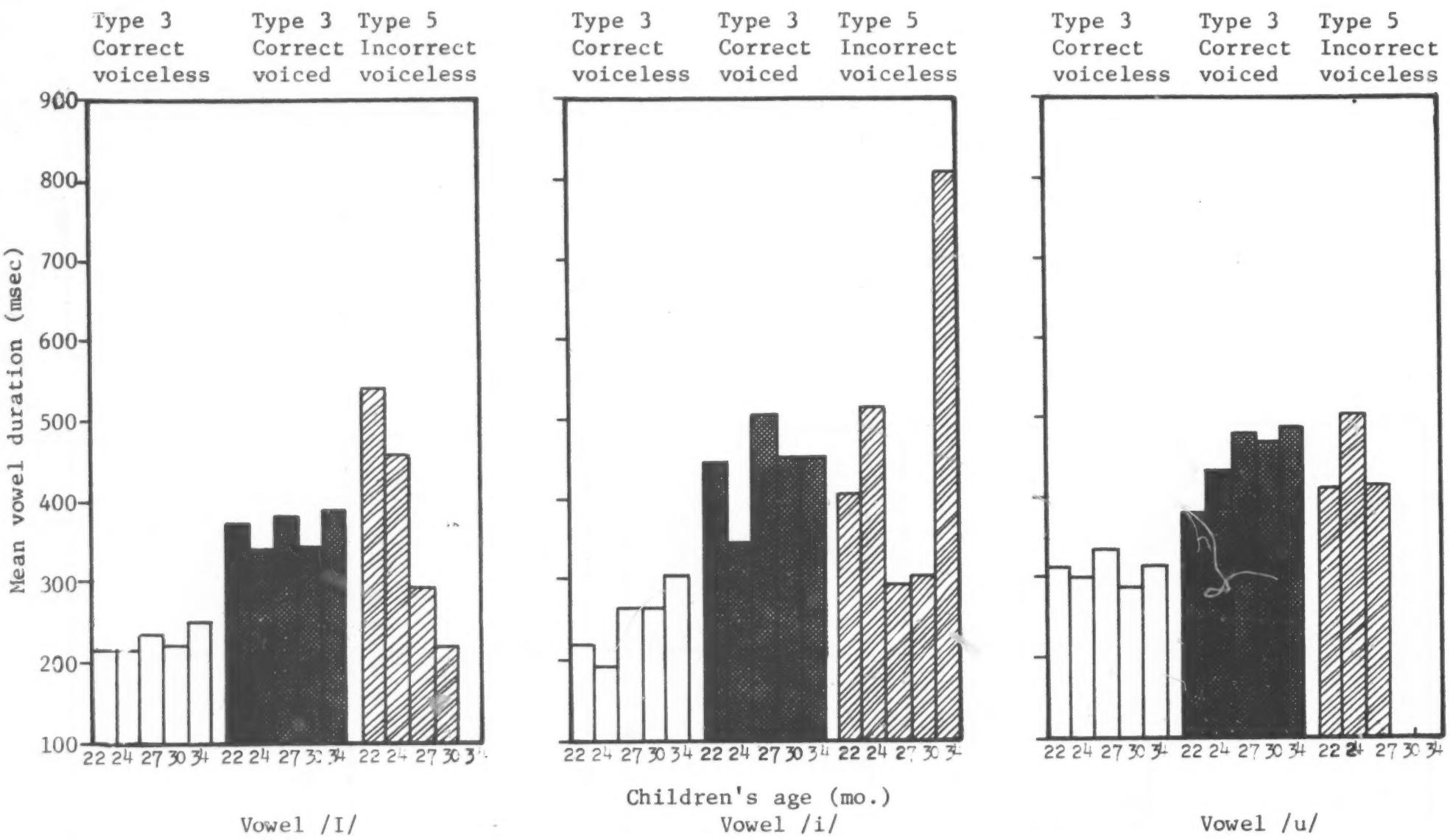

Fig. 7 First study, mean vowel duration for /I/, /i/, /u/, before correctly used voiceless and voiced fricatives and before voiceless fricatives substituted for voiced fricatives, as a function of children's age.

correctly used voiced fricatives than to those before the correctly used voiceless fricatives. Thus, vowel duration for /I/ before incorrectly substituted final response consonants was usually closer to the expected vowel duration before the stimulus consonant than to the incorrectly substituted response consonant.

Final fricatives after /i/. Table 6 shows that the children at 22 months produced the final voiceless fricative (here /θ/) with 33% error and they had a decreasing error rate until 34 months where there were no errors. This table also shows that at 22 months they produced the final voiced fricative (/z/) with a 41% error rate, and had a decreasing error rate until 34 months where there was only 4% error.

Scoring procedure type 1 on Table 8 and Fig. 8 shows, however, that despite the incorrect production of some of the final fricatives, correct differential vowel duration was produced continuously from the mean age of 22 months, when vowel duration before voiceless fricatives was 52% of that before voiced fricatives. At 34 months the vowel duration before voiceless fricatives was 62% of that before voiced fricatives.

The same pattern was seen at 22, 27, 30 and 34 months in Type 2. At 24 months, in Type 2, however, mean vowel duration before all voiceless fricatives (correct and incorrect) was 360, and before all voiced fricatives (correct and incorrect) was 351. This was due to the unusually long durations for before voiceless fricatives (645) produced by child 8 in session 3, where she substituted voiceless fricatives for the stimulus voiced fricative.

Table 8

First study, children's responses to picture stimuli. Mean vowel duration (msec) and duration ratio for /i/ before fricatives in /tiθ/, /piz/, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
1	7	24	174	360	.48	203	380	.53	174	380	.46	---	---	---	---
1	8	21	236	496	.48	550	---	---	---	---	---	236	496	550	---
1	9	21	266	435	.61	298	510	.58	266	510	.52	---	360	360	---
1	Mean	22	225	430	.52	350	445	.78	220	445	.49	236	392	410	---
3	7	26	188	325	.58	229	303	.75	188	303	.62	---	390	390	---
3	8	23	391	645	.61	645	---	---	---	---	---	391	645	645	---
3	9	23	206	398	.52	206	398	.52	206	398	.52	---	---	---	---
3	Mean	24	262	456	.57	360	351	1.02	198	351	.56	391	518	518	---
1-3	1	27.6	419	362	1.15	298	386	.77	298	386	.77	---	662	---	---
1-3	2	28.5	192	494	.38	192	605	.31	192	605	.31	---	382	---	---
1-3	3	25	320	916	.34	320	1075	.29	320	1075	.29	---	820	---	---
1-3	4	25.6	238	260	.91	284	190	1.49	260	190	1.36	255	256	298	---
1-3	5	27.6	283	346	.81	283	356	.79	283	356	.79	---	445	---	---
1-3	6	28	395	474	.83	396	474	.83	238	432	.55	---	---	---	---
1-3	Mean	27	308	475	.64	296	514	.57	265	507	.52	255	442	298	---
4-6	1	31.5	300	415	.72	300	415	.72	300	415	.72	---	---	---	---
4-6	2	31	180	392	.45	195	422	.46	180	422	.42	---	305	305	---
4-6	3	29	322	812	.39	322	435	.74	322	435	.74	---	1252	---	---
4-6	4	29	238	260	.91	212	466	.45	212	466	.45	245	---	---	---
4-6	5	31.5	303	403	.75	303	403	.75	303	403	.75	---	---	---	---
4-6	6	31	396	474	.83	264	582	.45	264	582	.45	---	---	---	---
4-6	Mean	30.2	290	459	.63	266	454	.58	264	454	.58	245	778	305	---
7-10	1	34.5	344	495	.69	344	495	.69	344	495	.69	---	---	---	---
7-10	2	34.5	192	494	.38	186	296	.62	186	296	.62	---	---	---	---
7-10	3	32.5	260	590	.44	306	546	.56	260	546	.47	---	650	810	---
7-10	4	31.5	330	516	.63	330	516	.63	330	516	.63	---	---	---	---
7-10	5	34.5	438	606	.72	438	605	.72	438	606	.72	---	---	---	---
7-10	6	34.5	294	281	1.04	294	281	1.04	294	281	1.04	---	---	---	---
7-10	Mn.	33.9	310	497	.62	316	456	.69	308	456	.67	---	650	810	---
	Parent No.														
1-3	7								268	620	.43				
1-3	8								267	490	.54				
1-3	9								270	443	.60				
1-3	1								212	345	.62				
1-3	2								236	420	.56				
1-3	3								194	388	.50				
1-3	4								225	535	.42				
1-3	5								198	349	.57				
1-3	6								182	390	.47				
1-3	Mean								228	442	.52				

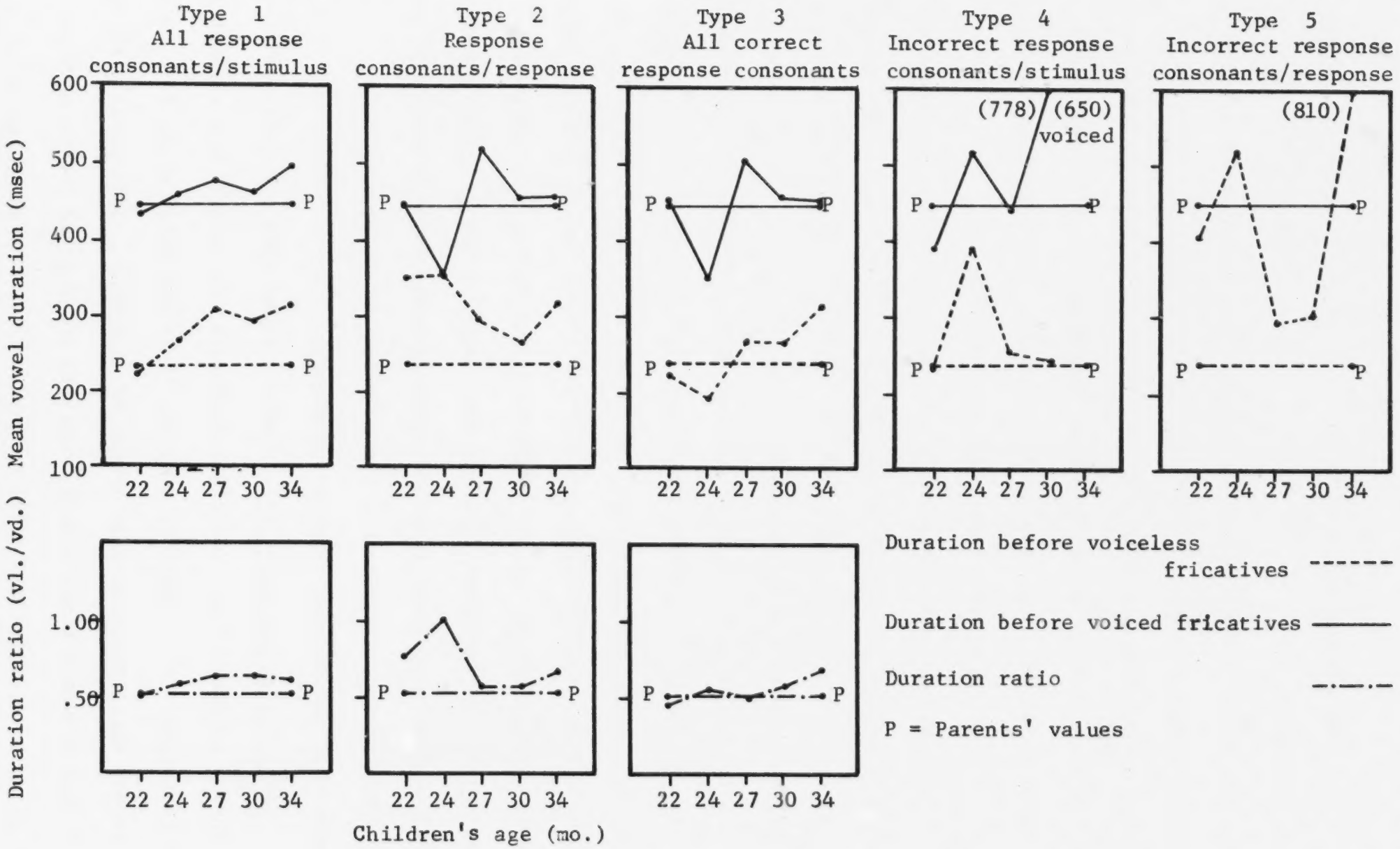

Fig. 8 First study, children's responses to picture stimuli. Mean vowel duration and duration ratio for /i/ before fricatives in /tiθ/, /piz/, as a function of children's age.

The same pattern which was seen in scoring procedure type 1 was seen in Type 3.

The actual response consonants which were substituted for the stimulus voiceless fricative /θ/ are shown in Table 6. Throughout all age groups the most common non-voiceless fricative substitution for /θ/ was /t/ with 14 occurrences. The most common voiceless fricative substitution, /s/, was used frequently. However, this was not considered to be an incorrect class substitution.

The response consonants which were substituted for the stimulus voiced fricative /z/ are shown in Table 6. Throughout all age groups, the most common substitutions for /z/ were /s/ with 14 occurrences, /Ø/ (open syllable) with 6 occurrences and /ts/ with 4 occurrences.

Scoring procedure types 4 and 5 are listed in Table 8 and displayed in Fig. 8. They are discussed in detail in Appendix D. Fig. 7 shows that mean vowel duration before voiceless fricatives incorrectly substituted for the voiced fricative /z/ was closer to the duration before correctly used voiced fricatives than to that before the correctly used voiceless fricatives. Thus, vowel duration for /i/ before incorrectly substituted final response consonants was usually closer to the expected vowel duration before the stimulus consonant than before the incorrectly substituted response consonant.

Final fricatives after /u/. Table 6 shows that the children at 22 months produced final voiceless fricative (/s/) with no errors at 22 and 24 months. At 27 months, however, there was a 22% error rate which decreased until there were no errors at 34 months. This table also shows that they produced final voiced fricative (/z/) at 22 months with a 33% error rate, which decreased to an 8% error rate at 34 months.

Scoring procedure type 1 on Table 9 and Fig. 9 shows, however, that despite the incorrect production of some of the final fricatives, correct differential vowel duration was produced continuously from the mean age of 22 months, when vowel duration before voiceless fricatives was 82% of that before voiced fricatives. At the mean age of 34 months, the vowel duration before voiceless fricatives was 64% of that before voiced fricatives. This same pattern was seen in Analyses 2 and 3.

The actual response consonants which were substituted for the stimulus voiceless fricative /s/ are shown in Table 6. Throughout all age groups, the most common substitution for /s/ was the voiceless affricate /ts/ with 6 occurrences.

The response consonants which were substituted for the stimulus voiced fricative /z/ are shown in Table 6. Throughout all age groups, the most common substitutions for /z/ were /Ø/ (open syllable) with 12 occurrences, and voiceless fricative /s/ with 7 occurrences.

Scoring procedure types 4 and 5 are listed in Table 9 and displayed in Fig. 9. They are discussed in detail in Appendix D. Figure 7 shows that the mean vowel duration before voiceless fricatives incorrectly substituted for the voiced fricative /z/ was closer to that before the correctly used voiced fricatives than to that before the correctly used voiceless fricatives. Thus, vowel duration for /u/ before incorrectly substituted final response consonants was usually closer to the expected vowel duration before the stimulus consonant to that before the incorrectly substituted response consonants.

Table 9

First study, children's responses to picture stimuli. Mean vowel duration (msec) and duration ratio for /u/ before fricatives in /gus/, /ʃuz/, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
1	7	24	205	311	.66	205	311	.66	205	311	.66	---	---	---	---
1	8	21	412	378	1.09	412	385	1.07	412	385	1.07	---	370	---	---
1	9	21	312	438	.71	346	460	.75	312	460	.68	---	415	415	---
1	Mean	22	310	375	.82	321	385	.83	310	385	.80	---	392	415	---
3	7	26	238	386	.62	238	386	.62	238	386	.62	---	---	---	---
3	8	23	371	556	.67	398	573	.69	371	573	.65	---	505	505	---
3	9	23	298	345	.87	298	345	.87	298	345	.87	---	---	---	---
3	Mean	24	302	429	.70	312	434	.71	302	434	.69	---	505	505	---
1-3	1	27.6	310	325	.95	301	---	---	286	---	---	---	325	430	---
1-3	2	28.5	315	548	.57	315	548	.57	315	548	.57	---	---	---	---
1-3	3	25	486	816	.59	265	590	.44	265	590	.44	454	1042	---	---
1-3	4	25.6	280	352	.79	370	330	1.12	422	330	1.27	210	402	415	---
1-3	5	27.6	313	443	.70	313	443	.70	313	443	.70	---	---	---	---
1-3	6	28	428	522	.81	428	522	.81	428	522	.81	---	---	---	---
1-3	Mean	27	355	501	.70	332	486	.68	338	486	.69	348	590	422	---
4-6	1	31.5	290	374	.77	290	408	.71	290	408	.71	---	255	---	---
4-6	2	31	224	332	.67	224	332	.67	224	332	.67	---	---	---	---
4-6	3	29	284	606	.46	284	566	.50	284	566	.50	---	780	---	---
4-6	4	29	320	506	.63	330	506	.65	330	506	.65	455	---	---	---
4-6	5	31.5	322	459	.70	322	459	.70	322	459	.70	---	---	---	---
4-6	6	31	238	432	.55	302	548	.55	302	548	.55	---	---	---	---
4-6	Mean	30.2	280	452	.61	292	470	.65	292	470	.62	455	518	---	---
7-10	1	34.5	352	460	.76	352	475	.74	352	475	.74	---	570	---	---
7-10	2	34.5	264	326	.80	264	326	.80	264	326	.80	---	---	---	---
7-10	3	32.5	225	524	.42	225	523	.43	225	523	.43	---	525	---	---
7-10	4	31.5	322	588	.54	322	588	.54	322	588	.54	---	---	---	---
7-10	5	34.5	488	606	.80	488	612	.79	488	612	.79	---	565	---	---
7-10	6	34.5	238	432	.55	238	432	.55	238	432	.55	---	---	---	---
7-10	Mn.	33.9	314	489	.64	315	492	.64	314	492	.63	---	553	---	---
	Parent No.														
1-3	7								312	589	.53				
1-3	8								302	474	.64				
1-3	9								283	384	.74				
1-3	1								230	355	.65				
1-3	2								236	390	.61				
1-3	3								213	360	.60				
1-3	4								265	455	.58				
1-3	5								216	326	.66				
1-3	6								198	408	.49				
1-3	Mean								250	416	.60				

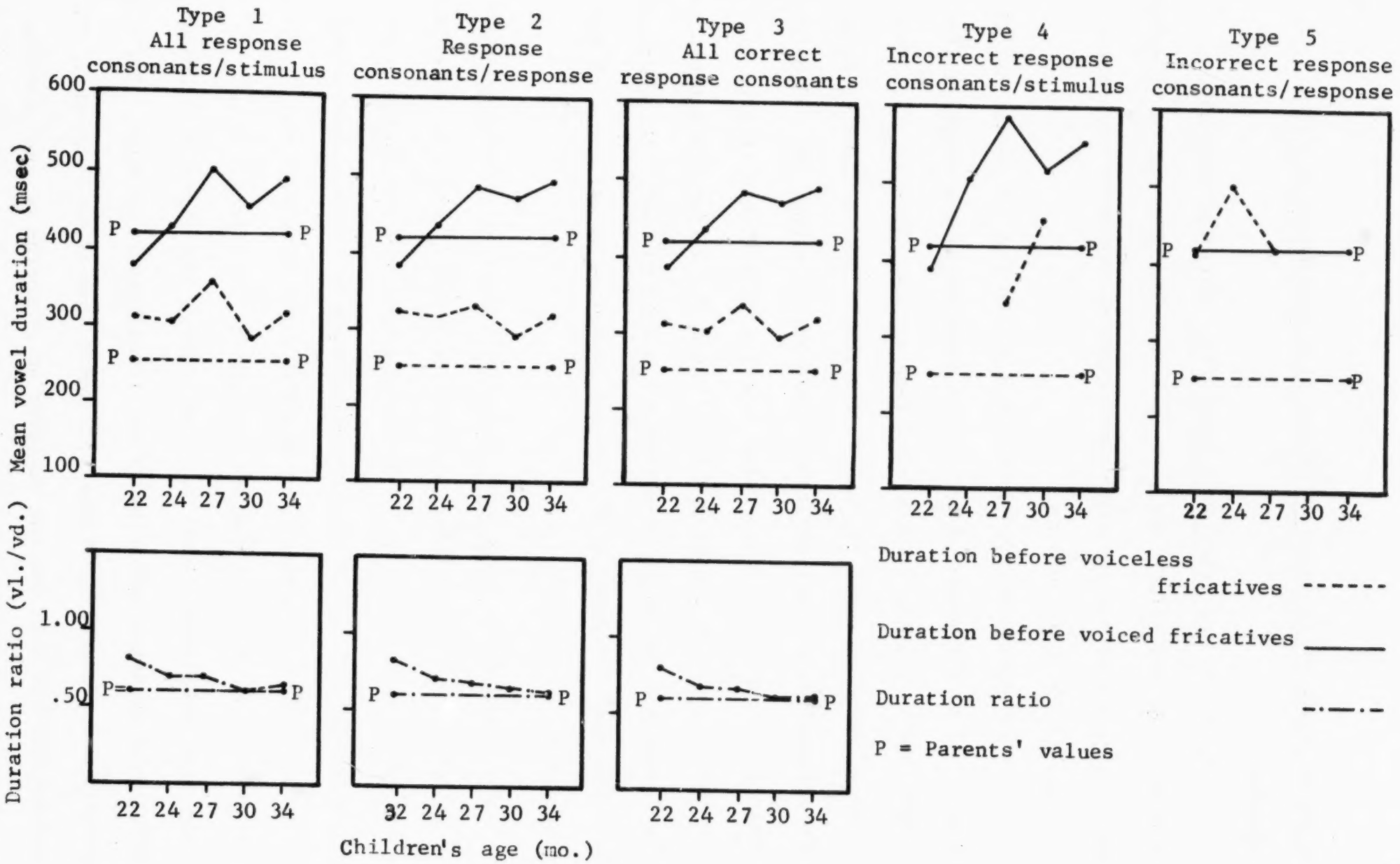

Fig. 9 First study, children's responses to picture stimuli. Mean vowel duration and duration ratio for /u/ before fricatives in /gus/, /ʃuz/, as a function of children's age.

Vowel duration in relation to manner of articulation of final consonants

Final stops and fricatives after /I/. Children were able to produce stops and fricatives correctly from the mean age of 22 month on. There was rarely any confusion regarding manner of production, as there had been in voicing.

Scoring procedure type 1 on Table 10 and Fig. 10 shows that children at 22 months produced mean vowel duration before stops at 198, and longer vowel duration before fricatives at 324. This is a 126 msec difference, which compares favorably with the 97 msec difference between the parents' mean vowel duration of 176 before stops, and 273 before fricatives.[8] The comparison holds also for Type 2, and is even closer for Type 3 (correct responses only), where the difference between mean vowel duration before stops and fricatives is 93 msec. This pattern is also the case for ages 24, 27, 30 and 34 months on all types of scoring procedures.

Final stops and fricatives after /i/. Scoring procedure type 1 on Table 11 and Fig. 11 shows that children at 22 months produced mean vowel duration before stops at 263, and longer vowel duration before fricatives at 328. This is a 65 msec difference which compares well with the 90 msec difference the parents' means show with the duration of 244 before stops and 334 before fricatives. This comparison holds even closer for Type 3 where the difference between mean vowel duration before stops and fricatives is 87 msec. The same pattern was produced for Types 1, 2 and 3 from 27 to 34 months. This pattern did not hold for the children at 24 months of age, however,

Table 10

First study, children's responses to picture stimuli. Mean vowel duration (msec) for /I/ before stops and fricatives, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim St.	Fr.	Type 2 Response cons/resp St.	Fr.	Type 3 All correct resp cons St.	Fr.
1	7	24	209	282	209	282	209	282
1	8	21	220	394	220	394	160	246
1	9	21	165	296	198	296	178	296
1	Mean	22	198	324	209	324	182	275
3	7	26	208	225	208	225	208	225
3	8	23	272	376	272	376	205	292
3	9	23	156	298	158	258	156	298
3	Mean	24	212	300	204	286	193	272
1-3	1	27.6	252	357	235	357	208	357
1-3	2	28.5	230	338	230	338	230	364
1-3	3	25	276	480	276	486	276	389
1-3	4	25.6	166	270	166	250	110	214
1-3	5	27.6	197	258	195	258	204	255
1-3	6	28	210	278	210	278	210	278
1-3	Mean	27	222	330	218	328	206	310
4-6	1	31.5	162	319	161	319	161	319
4-6	2	31	188	221	188	221	189	221
4-6	3	29	150	307	150	307	150	307
4-6	4	29	205	238	214	226	187	238
4-6	5	31.5	240	313	240	316	240	316
4-6	6	31	182	335	199	298	199	298
4-6	Mean	30.2	188	288	192	281	188	283
7-10	1	34.5	216	376	216	376	210	376
7-10	2	34.5	155	218	155	218	155	218
7-10	3	32.5	178	258	185	258	185	258
7-10	4	31.5	265	358	265	358	265	358
7-10	5	34.5	299	424	299	424	282	424
7-10	6	34.5	134	292	134	292	134	292
7-10	Mn.	33.9	208	321	209	321	205	321
	Parent No.							
1-3	7						200	363
1-3	8						255	356
1-3	9						212	318
1-3	1						160	237
1-3	2						152	257
1-3	3						142	206
1-3	4						162	272
1-3	5						142	210
1-3	6						165	241
1-3	Mean						176	273

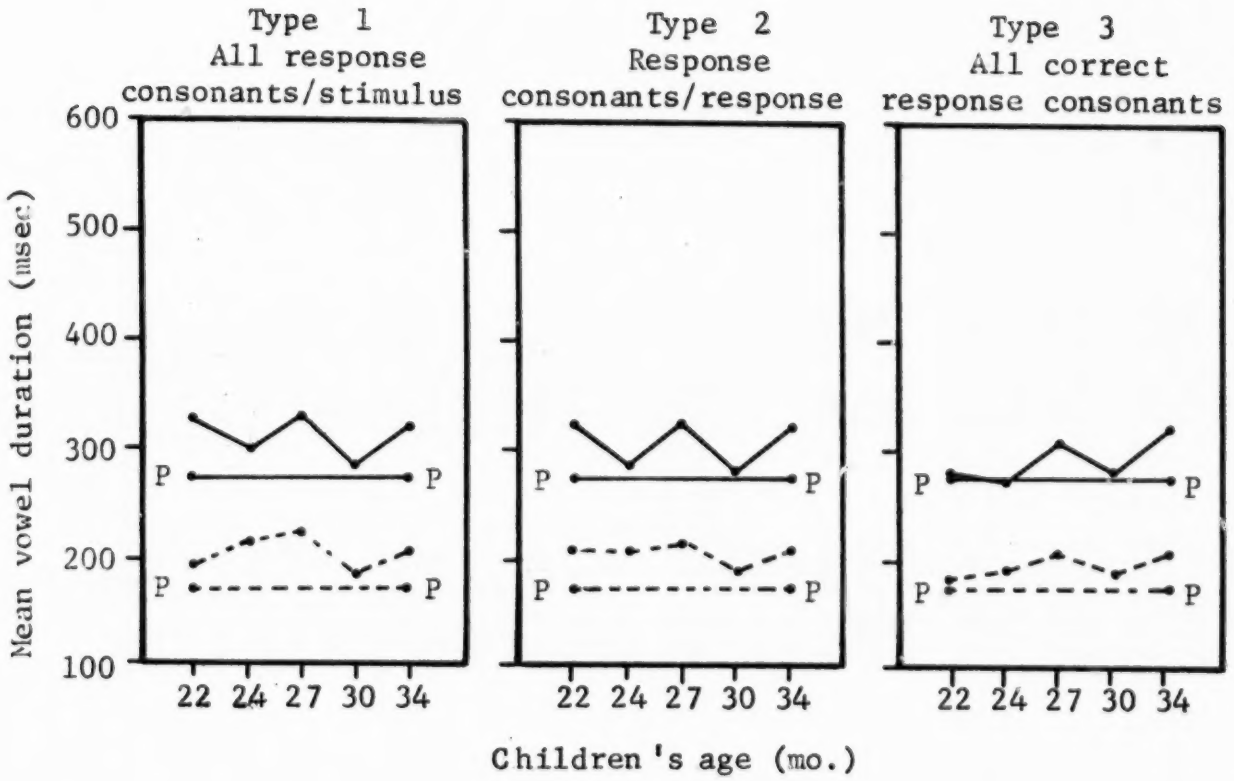

Fig. 10 First study, children's responses to picture stimuli. Mean vowel duration for /I/ before stops and fricatives, as a function of children's age.

Table 11

First study, children's responses to picture stimuli. Mean vowel duration (msec) for /i/ before stops and fricatives, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim St.	Type 1 All resp. cons/stim Fr.	Type 2 Response cons/resp St.	Type 2 Response cons/resp Fr.	Type 3 All correct resp cons St.	Type 3 All correct resp cons Fr.
1	7	24	291	266	291	292	291	276
1	8	21	276	366	262	550	215	---
1	9	21	222	350	263	403	228	388
1	Mean	22	263	328	272	415	245	332
3	7	26	258	256	258	266	258	246
3	8	23	548	518	495	645	508	---
3	9	23	348	302	348	302	348	302
3	Mean	24	385	359	368	404	372	274
1-3	1	27.6	288	390	296	367	296	367
1-3	2	28.5	374	343	462	294	532	294
1-3	3	25	270	618	270	698	270	698
1-3	4	25.6	280	348	272	252	276	225
1-3	5	27.6	344	315	326	319	293	319
1-3	6	28	274	435	272	435	182	335
1-3	Mean	27	305	408	316	394	308	373
4-6	1	31.5	215	358	233	358	228	358
4-6	2	31	220	286	220	308	220	301
4-6	3	29	419	567	368	362	368	362
4-6	4	29	280	348	304	381	290	381
4-6	5	31.5	225	353	225	353	225	353
4-6	6	31	274	435	303	423	303	423
4-6	Mean	30.2	272	391	276	364	272	363
7-10	1	34.5	318	419	296	419	296	419
7-10	2	34.5	374	343	214	241	214	241
7-10	3	32.5	316	425	330	426	326	404
7-10	4	31.5	330	423	330	423	330	423
7-10	5	34.5	385	522	385	522	385	521
7-10	6	34.5	358	288	358	288	358	288
7-10	Mn.	33.9	346	403	318	386	318	382
	Parent No.							
1-3	7						292	444
1-3	8						339	379
1-3	9						258	356
1-3	1						189	278
1-3	2						234	328
1-3	3						196	290
1-3	4						264	380
1-3	5						193	273
1-3	6						239	286
1-3	Mean						244	334

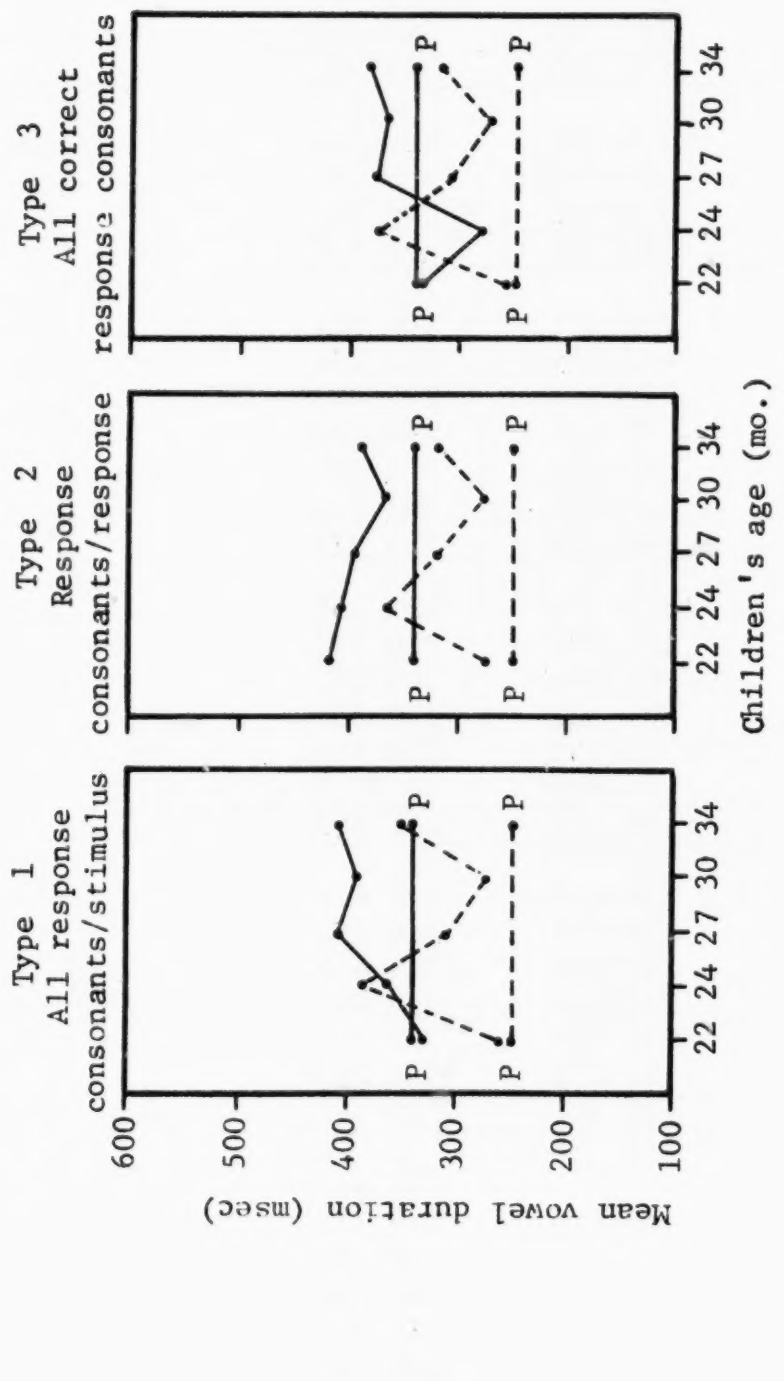

Fig. 11 First study, children's responses to picture stimuli. Mean vowel duration for /i/ before stops and fricatives, as a function of children's age.

where the reverse was true. Each of the 3 children at the mean age of 24 months reversed the relative durations in scoring procedure types 1 and 3. The reversal did not show up in scoring procedure type 2, however, where the pattern was correct for 2 of the 3 children.

Final stops and fricatives after /u/. Scoring procedure type 1 on Table 12 and Fig. 12 shows that children at 22 months produced mean vowel duration before stops at 260, and before fricatives at 342. This is a 82 msec difference which compares well with the 81 msec difference the parents' means show, with a 251 duration before stops, and 332 before fricatives. The comparison also holds up for scoring procedure type 2 and is also very close for Type 3 (correct responses only) where the difference between mean vowel duration before stops and fricatives is 100 msec. This pattern is also true for ages 24, 27, 30 and 34 months on all scoring procedure types.

Intrinsic vowel duration

Scoring procedure type 1 on Table 13 and Fig. 13 shows that children at 22 months produced correct differential intrinsic vowel duration, with mean vowel durations of 261 for the lax vowel /I/, 296 for the tense vowel /i/, and 302 for the tense vowel /u/. These durations compare exceptionally well with those of the parents' means of 225 for /I/, 290 for /i/, and 292 for /u/. It is important to note that in the children's production in scoring procedure type 1, the lax vowel is 38 msec shorter than the tense vowels (it is 66 msec shorter in the parents' production) and the tense vowels are approximately equal in

Table 12

First study, children's responses to picture stimuli. Mean vowel duration (msec) for /u/ before stops and fricatives, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim St.	Type 1 All resp. cons/stim Fr.	Type 2 Response cons/resp St.	Type 2 Response cons/resp Fr.	Type 3 All correct resp cons St.	Type 3 All correct resp cons Fr.
1	7	24	258	258	266	258	248	258
1	8	21	292	395	330	398	272	398
1	9	21	231	375	245	403	221	386
1	Mean	22	260	342	280	353	247	347
3	7	26	233	312	233	312	233	312
3	8	23	383	463	383	486	311	472
3	9	23	312	321	312	322	312	321
3	Mean	24	310	366	310	373	285	368
1-3	1	27.6	379	318	344	301	335	286
1-3	2	28.5	324	431	316	431	316	431
1-3	3	25	496	651	496	428	496	428
1-3	4	25.6	389	316	451	342	339	376
1-3	5	27.6	354	378	3[illegible]	378	356	378
1-3	6	28	362	475	36[illegible]	475	362	475
1-3	Mean	27	384	428	389	392	367	396
4-6	1	31.5	296	332	296	348	296	348
4-6	2	31	258	278	258	278	258	278
4-6	3	29	326	372	326	359	326	359
4-6	4	29	392	412	392	418	392	418
4-6	5	31.5	315	390	315	390	315	390
4-6	6	31	182	335	386	425	373	425
4-6	Mean	30.2	294	353	328	370	326	370
7-10	1	34.5	358	406	358	413	310	413
7-10	2	34.5	206	295	206	295	206	295
7-10	3	32.5	296	374	296	336	296	336
7-10	4	31.5	443	455	443	455	443	455
7-10	5	34.5	372	548	374	550	373	550
7-10	6	34.5	182	335	182	335	182	335
7-10	Mn.	33.9	310	402	310	397	302	397
	Parent No.							
1-3	7						305	450
1-3	8						324	388
1-3	9						241	334
1-3	1						220	292
1-3	2						240	312
1-3	3						212	287
1-3	4						258	360
1-3	5						202	271
1-3	6						258	302
1-3	Mean						251	332

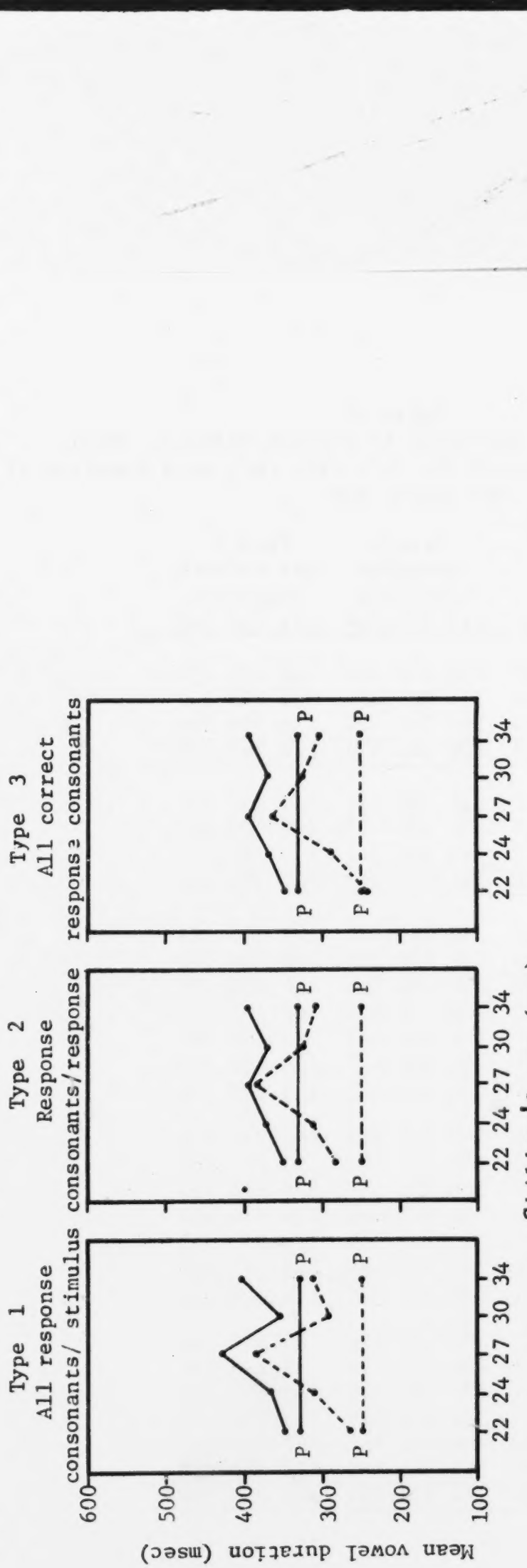

Fig. 12 First study, children's responses to picture stimuli. Mean vowel duration for /u/ before stops and fricatives, as a function of children's age.

Table 13

First study, children's responses to picture stimuli. Mean intrinsic vowel duration (msec) for /I/, /i/, /u/, as a function of children's age

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim /I/	/i/	/u/	Type 2 Response cons/resp /I/	/i/	/u/	Type 3 All correct resp cons /I/	/i/	/u/
1	7	24	246	279	258	246	291	262	246	284	253
1	8	21	308	321	344	308	406	364	203	215	356
1	9	21	230	286	303	247	334	324	236	308	304
1	Mean	22	261	296	302	266	344	316	228	269	304
3	7	26	216	258	272	216	262	272	216	252	272
3	8	23	324	533	423	324	570	451	248	508	418
3	9	23	227	325	317	245	325	317	232	325	317
3	Mean	24	256	372	338	262	386	347	232	362	336
1-3	1	27.6	306	346	348	314	335	336	302	335	324
1-3	2	28.5	276	358	378	284	370	373	285	394	373
1-3	3	25	378	444	574	346	484	526	314	484	525
1-3	4	25.6	218	264	352	208	268	408	162	262	373
1-3	5	27.6	222	330	366	222	319	369	224	308	363
1-3	6	28	244	354	418	244	353	418	244	258	418
1-3	Mean	27	274	349	406	270	354	405	255	340	396
4-6	1	31.5	240	286	314	240	310	322	240	328	322
4-6	2	31	205	254	268	205	264	268	205	261	268
4-6	3	29	228	493	360	228	372	353	228	372	353
4-6	4	29	222	331	402	222	342	404	214	336	404
4-6	5	31.5	276	289	353	274	289	353	274	289	353
4-6	6	31	258	354	258	248	363	405	248	363	399
4-6	Mean	30.2	238	334	326	236	323	400	234	324	350
7-10	1	34.5	296	368	382	307	358	380	305	358	364
7-10	2	34.5	186	358	250	186	228	250	186	228	250
7-10	3	32.5	218	370	335	222	378	320	222	365	320
7-10	4	31.5	312	376	449	312	376	449	311	376	449
7-10	5	34 5	362	454	460	368	453	462	362	453	462
7-10	6	34.5	213	322	258	213	322	258	213	322	258
7-10	Mn.	33.9	264	374	356	268	352	353	266	350	350
	Parent No.										
1-3	7								282	368	378
1-3	8								306	359	356
1-3	9								265	307	287
1-3	1								198	234	256
1-3	2								204	281	276
1-3	3								174	244	250
1-3	4								218	322	309
1-3	5								176	233	237
1-3	6								203	263	280
1-3	Mean								225	290	292

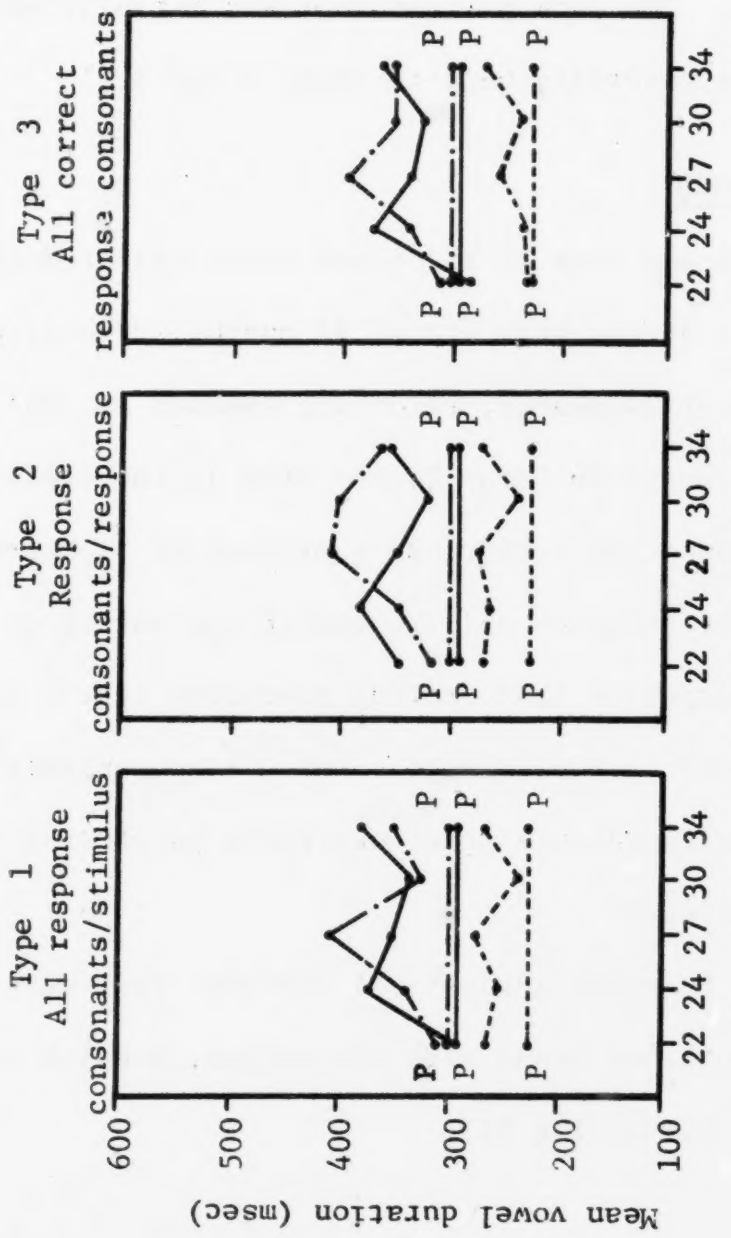

Fig. 13 First study, children's responses to picture stimuli. Mean intrinsic vowel duration for /I/, /i/, /u/, as a function of children's age.

duration as is the case in the adult model. The same pattern is true for the other age groups in Type 1, although intrinsic vowel duration for the tense vowels /i/ and /u/ tends to become increased overall as a function of increasing age. The same pattern that was established in Scoring procedure type 1 is generally held in Types 2 and 3.

STATISTICAL ANALYSIS OF RESULTS

A statistical analysis was done on the vowel durations produced by the 3 children from Group 2 at the mean age of 22 months, recording session 1, and the mean age of 24 months, recording session 3. Only the responses for the 3 children in Group 2 were used in the statistical analysis, not Group 1, because the former had a minimum of 3 observations per child per word per session, and the latter had only 1 or 2 or sometimes none. Only responses from Scoring procedure type 1 (All response consonants/stimulus) were used. In session 1 approximately 29% of these final response consonants were incorrect; in session 3, approximately 17% were incorrect.

A completely repeated measures analysis of variance test was performed on these vowel duration means with the design, session (2) by vowel (3) by manner (2) by voicing (2).

Vowel duration was significantly increased before the final consonant when the stimulus consonant was voiced rather than voiceless ($F(1,2) = 402.15$, $p < .01$). The mean vowel duration before stimulus voiceless consonants at 22 months was 213, at 24 months, 244, and that before stimulus voiced consonants at 22 months was 365, at 24 months, 399. This produced the correct voiceless/voiced ratios of 59% at 22 months, and 61% at 24 months.

The 3 separate vowels showed significant differences in intrinsic duration ($F(2,4) = 8.22$, $p < .05$). At 22 months, the lax vowel /I/ with the mean intrinsic duration of 261, was significantly shorter than the tense vowels /i/ and /u/ with the mean intrinsic durations of 296 and 302 respectively. At 24 months, the lax vowel /I/ was produced with the mean intrinsic vowel duration of 256. This was significantly shorter than the mean intrinsic durations for the tense vowels /i/ and /u/ which were 372 and 338 respectively.

There was a significant interaction between vowel quality and manner of the final stimulus consonant ($F(2,4) = 34.19$, $p < .01$). This showed up as a significant interaction because manner values observed with /i/ failed to show the expected difference of longer duration before fricatives than stops at 24 months as discussed earlier. Longer vowel duration was observed, however, before fricatives than stops for the vowels /I/ and /u/ at both ages.

SUMMARY

The answer to the main question asked in this study - At what age does production of correct differential vowel duration emerge? - is at, or before, 21 months, as evidenced by vowel durations produced before correct as well as incorrect final response consonants of the youngest subjects recorded, child 8 and child 9. It is, of course, beyond the scope of this study to speculate on production of differential vowel duration preceding 21 months of age. The mean vowel duration ratio for /I/ before voiceless vs. voiced stops at 22 months was .49 and for fricatives was .50. The parents' ratios for the above were .60 and .46 respectively. The same pattern was also seen for the vowels /i/ and /u/.

The longitudinal study involved a careful examination of the acoustic evidence for 1) the development of control of manner and voicing of the final consonant and 2) the development of differential vowel duration in relation to 1). Regarding the first point, the children produced final voiceless stops with the lowest error rates (with the vowel /I/, 0%; with /i/, 11% - 2%; with /u/, 0%). Their control of final voiceless fricatives was somewhat slower in development than for final voiceless stops (with the vowel /I/, 5% - 0%; with /i/, 33% - 0%; and with /u/, 22% - 0%). The greatest errors, however, were in control of voicing for the voiced stops and the voiced fricatives, where the most common substitutions which occurred were the voiceless counterparts of the voiced stimuli. Children produced final voiced stops with the following error rates: with /I/, 50% - 2%; with /i/, 50% - 2%; and with /u/, 50% - 2%. Final voiced fricatives occurred with the following error rates: with /I/ 33% - 0%, with /i/ 41% - 4%, and with /u/ 33% - 8%.

In every case, errors in control of voicing decreased from age 22 to 34 months. There were very few problems in control of manner of articulation, and stops were never confused with fricatives, as had been the case for voicing.

Control of voicing and manner of the final consonant did not emerge earlier with either the lax vowel /I/ or the tense vowels /i/ or /u/, as seen in the table below:

Error rates for final response consonants, as a function of children's age

	Children's age (mo.)					
	22	24	27	30	34	Overall
Vowel /I/	20%	16%	15%	8%	.5%	11.9%
Vowel /i/	33%	26%	21%	10%	2%	18%
Vowel /u/	20%	10%	22%	2%	3%	11.4%

The increased overall error rate for the vowel /i/ was probably due to the morphological irregularity of the word /fit/ with which that vowel occurred.

Regarding the second point, (the development of differential vowel duration in relation to development of control of manner and voicing of the final consonant), from the age of 21 months on, the children produced correct differential vowel duration for /I/, /i/, and /u/, appropriate for voicing and manner of the final stimulus consonant, not necessarily the final response consonant, even when it was incorrect. This was shown through scoring procedure type 4 which studied only vowel durations in responses which used incorrectly substituted response consonants and compared these vowel durations to those before response

consonants used correctly for the same stimulus words. There was usually less than a 50 msec difference. The same pattern was shown in scoring procedure type 5 where vowel duration before voiceless consonants substituted for voiced consonants was closer to that for correctly used voiced consonants (usually less than 50 msec difference), than correctly used voiceless consonants (usually more than 100 msec difference).

Thus, repeatedly, with few exceptions, when the final response consonant was incorrect in voicing and/or manner, the correct differential vowel duration produced was appropriate for the original stimulus consonant, not the response consonant. It is important to remember that each child had his own developing phonological system, however, and this was not analyzed in this study. Thus, the phonological role of differential vowel duration for any child at any age was not known. This study did show that production of correct differential vowel duration preceded correct production of voicing of final consonants.

FOOTNOTES (Chapter 2)

1. Author of the story was Mrs. Lora N. Mermin.
2. For example, if the stimulus picture was /bIb/ and the child said /bIp/ once, and /bIb/ once, the vowel durations produced in /bIp/ and in /bIb/ were both used in computing the mean vowel duration for /I/ before the stimulus voiced stop /b/.
3. For example, if the stimulus picture was /bIb/, and the child said /bIp/, the vowel duration in /bIp/ was used in computing the mean vowel duration for /I/ before voiceless stops and was averaged in with other productions of /I/ before voiceless stops as in the stimulus word /stIk/.
4. For example, if the stimulus picture was /bIb/, and the child said /bIp/ once, and /bIb/ once, the first response /bIp/ was not used and only the second response /bIb/ was counted for the mean vowel duration for /I/ before the stimulus voiced stop /b/.
5. For example, if the stimulus picture was /bIb/ and the child said /bIp/ once, and /bIm/ once, the vowel durations produced in both utterances were used to compute the mean vowel duration for /I/ before all response consonants incorrectly substituted for the voiced stop /b/.
6. For example, if the stimulus picture was /bIb/, and the child said /bIp/ once, and /bIm/ once, the vowel duration in /bIp/ was used to compute mean vowel duration for /I/ before voiceless stops substituted incorrectly for the voiced stop /b/ and the vowel duration in /bIm/ was not used at all.

FOOTNOTES continued

7. The only black subject in the study, child 8, made the most frequent use of voiceless substitutions for the voiced stimuli. This is not surprising, however, when one examines the production of final voiced stops by the mother. The parent consistently voiced and then devoiced all final voiced stops and heavily aspirated their release. This is a characteristic reported in phonological studies of adult speakers of black dialects (Luelsdorff, 1970). It appears here that the child is very sensitive to the production of the final release of these stops and is imitating that, thus consistently producing voiceless stops. A similar devoicing pattern appeared in production of final fricatives for that parent, and the child seems to have responded in a similar way.

8. This subjective evaluation and those which follow are based on the results of the studies mentioned in Footnote 3 in Chapter 1 and on the norms for parents in the first and second studies.

Chapter 3

SECOND STUDY: VOWEL DURATION IN CHILDREN'S RESPONSES ELICITED WITH TAPED STIMULI OF NORMAL DURATION

INTRODUCTION

This study investigated the development of production of correct differential vowel duration in utterances elicited with a stimulus tape which had stimulus words with correct differential vowel duration. The same main question asked in the first study - When does correct differential vowel duration emerge? was asked in this longitudinal study and the same groups of children were used.

The same fundamental observations made in the first study concerning development of 1) voicing of final stops 2) voicing of final fricatives and 3) manner of articulation of final stops and fricatives were made in this study. The following question was added, however: Was there any difference in the production of vowel duration in the words uttered in this study and those same words which were uttered with the picture story in the first study?

METHOD

STIMULUS MATERIALS

The close tense front vowel /i/ was chosen for this study in 8 CVC words where the final consonant was a voiceless stop, a voiced stop, a voiceless fricative or a voiced fricative. Four of the words were chosen from the stimulus words used in The Scary Goose Story: /fit/, /sid/, /tiθ/, /piz/. At the time this stimulus tape was prepared, the influence of the initial consonant on vowel duration was not known. Therefore, the remaining 4 words were chosen with the criterion that the initial consonant remain constant and that it be voiceless. These constant /#p--/ words were /pip/, /pib/, /pis/, /piz/. Each word was used twice in a tape.

A subsequent study with adult subjects (Naeser, 1970b) showed the initial consonant to increase vowel duration in a CVC word only if that initial consonant was voiced. Thus, because all initial consonants were voiceless in the story words, /fit/, /sid/, /tiθ/, /piz/ and in the constant /#p--/ words, it was not expected that vowel duration for the 2 sets of words would be different if all initial consonants were articulated correctly. However, for the following reasons, the 2 sets of words were still used and responses were treated separately. 1) Some of the constant /#p--/ words were perhaps unfamiliar to the children, e.g. /pip/, /pib/ and their responses for these words might differ from those for the familiar story words. 2) Responses for the story words in this study elicited with tape stimuli were separated for comparison with those responses for the same story words in the first study

elicited with picture stimuli, to test for any differences in vowel duration under the different stimulus conditions.

A male graduate student in linguistics who had experience in recording phonological items for testing recorded the stimulus tapes.[1] He recorded the words with a normal conversational list intonation pattern. Recording was done under the same conditions as described in Chapter 2.

Vowel duration measurements for the stimulus words were taken from duplex oscillograms produced and segmented as described in Appendix B.

SUBJECTS

Group 1

The same children who participated in the first study participated in this study for 7 months. The mean age was 27.6 months when this study began, and 33.2 months when the study was finished.

Group 2

The same children who participated in the first study participated in this study for 3 months. The mean age was 22 months when this study began, and 24 months when the study was finished.

PROCEDURE

A parent of each child accompanied him to the Department of Linguistics Phonetics Laboratory each month. The parent, the child and the experimenter sat at a table in a sound-treated booth and the

same recording equipment used in the first study was used here. The stimulus tape was played back on a Sony tape recorder (Model TC-777-4) which was outside the booth, at the recorded speed of 7½ i.p.s. and amplified in the sound-treated booth through a Sony amplifier (Model SSA 3). For a schematic diagram of this recording procedure see Fig. 14.

The child was taught how to push the Sony remote control buttons which played back the words from the stimulus tape. The experimenter said to the child, "Push the button and you will hear a man talk." The child then pushed the playback button and heard the male voice utter a word from the stimulus tape. The experimenter then stopped the tape and said to the child, "Say what the man just said." The child then uttered the word just played back from the stimulus tape. If the child uttered a totally incorrect word or did not hear the stimulus word, the experimenter used the remote control to wind the tape back and the same stimulus word was tested for again with the above procedure. This procedure was used for all words. After the child understood the task, there was no need for the experimenter to say, "Say what the man just said," and the recording session went on through the initiative of the child.

Each child in Group 1 completed Stimulus Tape A once one month, then stimulus Tape B once the next, and so on. Each child in Group 2 completed Stimulus Tape A twice in the first month; in the second month he was not asked to respond to Stimulus Tape A or B. In the third month, he was tested with Stimulus Tape A in the same way he had been in the first month.

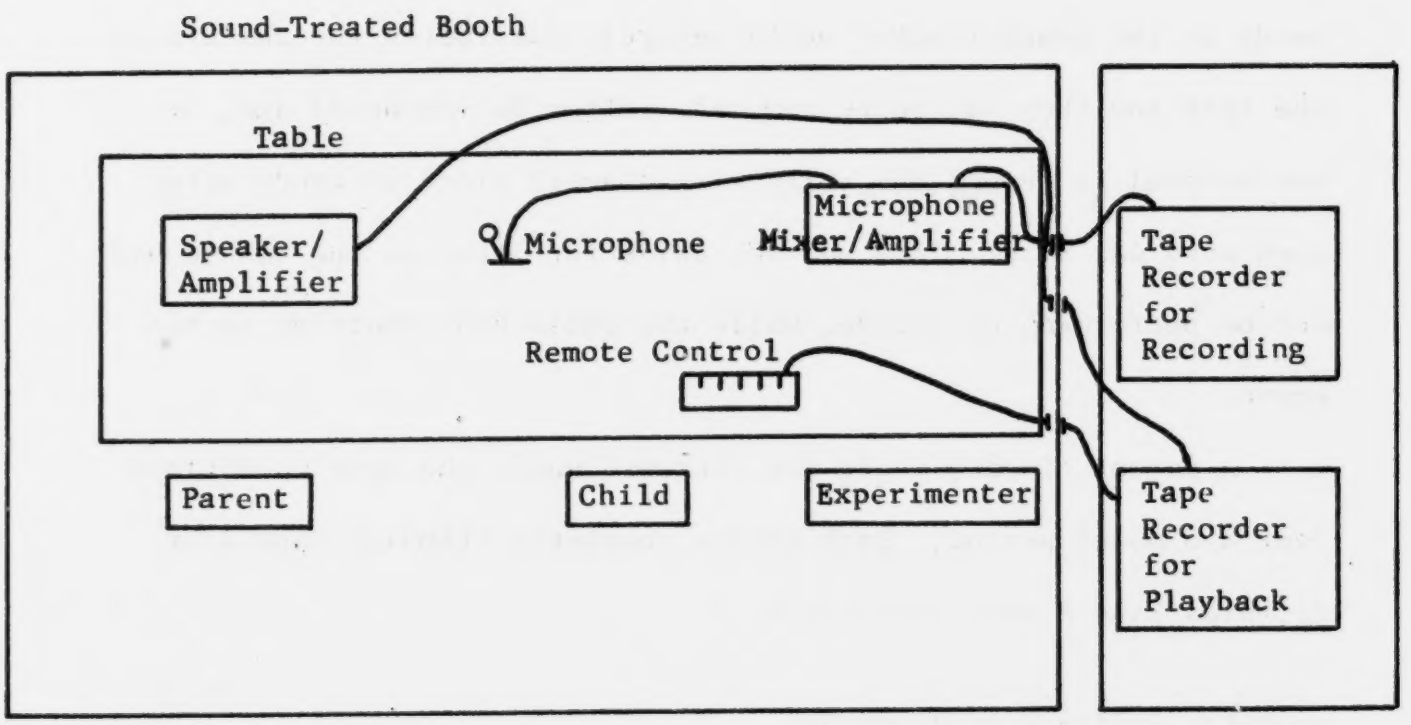

Fig. 14 Schematic diagram for recording utterances elicited with a stimulus tape at the Department of Linguistics Phonetics Laboratory

When the children were under 30 months of age, any toys or candy in the sound-treated booth severely distracted the child from the task and they had to be removed. After 30 months of age, it was helpful to reward the child with a small piece of candy after each word was said. This was set aside for later as the task could not be performed, of course, while the child had something in his mouth.

A parent of each child was recorded under the same conditions over a 3 month period. Each parent completed Stimulus Tape A or Stimulus Tape B once each month.

Acoustic Analysis of Responses

The responses were analyzed, transcribed and coded exactly as they were in the first study.

RESULTS AND DISCUSSION

The same 5 scoring procedure types which were used in the first study were used in this study.

Response utterances from the 9 children from the 2 groups in this longitudinal study were separated into 5 groupings based on age and recording session number in the following way:

Session No.	Mean Age (mo.)	No. of Children	Group No.
1	22	3	2
3	24	3	2
2-3	28	6	1
4-5	30	6	1
6-8	32	6	1

The vowel durations with /i/ were treated separately for the story words and the constant /#p--/ words, for reasons discussed earlier.

STATISTICAL ANALYSIS OF RESPONSES

The statistical analysis was done on the vowel durations produced by the 3 children in Group 2. Only the responses for the children in Group 2 were used in this analysis, not Group 1, because the former had a minimum of 3 observations per child per word per session, and the latter had only 1 or 2. Only responses from scoring procedure type 1 (All response consonants as a function of the stimulus) were used. In session 1 approximately 21% of the final response consonants were incorrect; in session 3, approximately 14% were incorrect.

To find out if the children were following the vowel duration of the stimulus tape, a completely repeated measures analysis of variance test was performed on the difference between the children's mean vowel durations and those on the tape, with the design, session (2) by word set (2) by manner (2) by voicing (2).

The overall mean vowel duration differences from the stimulus tape were significantly different between sessions 1 and 3 ($F(1,2) = 2100.79$, $p < .01$). The mean duration in session 1 (stimulus tape values given in parenthesis) was 292 msec (291), a difference of 1 msec from the stimulus tape, and in session 3, 321 (291), a difference of 30 msec. These overall differences are very small in absolute terms, however, and a 31 msec difference in performance over a 2-month period is probably not a very large difference in terms of speech production.

It is, however, probable that the children were imitating the durations on the tape in both sessions because not one other production factor showed up as significantly different from those on the tape at the $p < .05$ level. This will be discussed later with comparison of these vowel duration values with those produced with the picture stimuli for the vowel /i/ in the first study.

To test for significant differences in the actual vowel durations produced by the children, a completely repeated measures analysis of variance test was performed on the children's vowel duration means with the same design which was used above.

Mean vowel duration was not found to differ significantly for the 2 word sets used - story words vs. constant /#p--/ words. Thus, the children treated the unfamiliar words as they had the story words in this study and the following results hold for both sets of words.

In the children's utterances, vowel duration was significantly greater before stimulus voiced consonants than before stimulus voiceless consonants ($F(1,2) = 63.68$, $p < .05$). The children's mean vowel duration (stimulus tape values given in parenthesis) before voiceless consonants was 212 (207) and before voiced consonants, 401 (376). The children's voiceless-to-voiced ratio was .52 (.55). This is a similar finding to that in the first study where there was a significant difference between the duration before voiceless consonants, 243, and before voiced consonants, 424. The voiceless-to-voiced ratio in the first study was .57.

The children's vowels were significantly longer before final stimulus fricatives than before stimulus stops ($F(1,2) = 22.30$, $p < .05$). For children, the mean vowel duration before stops (stimulus tape values given in parenthesis) was 245 (200) and before fricatives, 368 (321). The difference between vowel duration before stops and fricatives was not significant in the first study. For that study, the value for /i/ was 324 before stops and 343 before fricatives.

DESCRIPTIVE ANALYSIS OF RESPONSES

Vowel duration in relation to voicing of final stops

Final stops after /i/ in story words. Table 14 lists the incorrect final response consonants substituted in /fit/ and /sid/ in this tape study. Comparison of the percentage of incorrect final response consonants in this study and the first study for the story words, /fit/ and /sid/, in the table below shows that in most age groups there were fewer errors with the tape stimulus than the picture stimulus.

Mean Age (mo.)		Percent incorrect final response consonants			
		/fit/		/sid/	
Tape	Picture	Tape	Picture	Tape	Picture
22	22	0%	8%	41%	50%
24	24	0%	0%	25%	33%
28	27	4%	11%	33%	25%
30	30	4%	8%	0%	16%
32	34	8%	2%	0%	2%

Table 14
Second study, children's responses to taped stimuli of normal duration.
Incorrect response consonants and missing responses
for /i/ before stops

Sess. No.	Mean Age(mo.)		/fit/ V1.st.	/sid/ Vd.st.	/pip/ V1.st.	/pib/ Vd.st.
1	22	Inc. resp. cons.	0	5/t/	0	4/m/
		No. inc. resps.	0	5	0	4
		% inc. resps.	0%	41%	0%	33%
		No. missing resps.	0	0	0	0
		% missing resps.	0%	0%	0%	0%
3	24	Inc. resp. cons.	0	1/t/ 1/n/ 1/Ø/	0	3/p/
		No. inc. resps.	0	3	0	3
		% inc. resps.	0%	25%	0%	25%
		No. missing resps.	0	0	0	0
		% missing resps.	0%	0%	0%	0%
2-3	28	Inc. resp. cons.	1/d/	6/t/ 1/n/ 1/v/	0	6/p/ 1/n/
		No. inc. resps.	1	8	0	7
		% inc. resps.	4%	33%	0%	29%
		No. missing resps.	3	2	3	1
		% missing resps.	12%	8%	12%	4%
4-5	30	Inc. resp. cons.	1/ts/	0	0	2/p/ 1/Ø/
		No. inc. resps.	1	0	0	3
		% inc. resps.	4%	0%	8%	12%
		No. missing resps.	0	0	1	0
		% missing resps.	0%	0%	4%	0%
6-8	32	Inc. resp. cons.	3/ts/	0	0	1/p/
		No. inc. resps.	3	0	0	1
		% inc. resps.	8%	0%	0%	2%
		No. missing resps.	0	0	0	0
		% missing resps.	0%	0%	0%	0%

This is to be expected since the entire CVC model was presented to the child immediately before he uttered the response. With the tape stimuli there was a small increasing error rate over age for the voiceless stop /t/, and a decreasing error rate for the voiced stop /d/. The substitutions followed the same pattern they had in the first study, i.e. for /t/, /ts/, which probably included the regular plural morpheme, and for /d/, the voiceless counterpart /t/.

Despite the incorrect production of some of the final response consonants, scoring procedure type 1 on Table 15 and Fig. 15 shows that correct differential vowel duration was produced throughout all age groups. The voiceless-to-voiced ratio was .51 at 22 months and .52 at 32 months. The stimulus tape ratio was .64, and that for the parents was .60. The same pattern was seen in scoring procedure types 2 and 3.

Scoring procedure types 4 and 5 are listed in Table 15 and displayed in Fig. 15. The same general pattern which was seen for vowel duration with incorrect final response consonants in the first study is seen in the incorrect responses in this study. As noted above, however, there were fewer incorrect responses with the tape

Table 15

Second study, children's responses to taped stimuli of normal duration. Mean vowel duration (msec) for /i/ before stops in /fit/, /sid/, as a function of children's age

Stim. tape: V1. st. /fit/ 208, Vd. st. /sid/ 325, V1./Vd. Ratio .64

Sess. No.	Child No.	Age (mo)	Type 1 All resp. cons/stim V1.	Vd.	Rat.	Type 2 Response cons/resp V1.	Vd.	Rat.	Type 3 All correct resp cons V1.	Vd.	Rat.	Type 4 Inc R cons/S V1.	Vd.	Type 5 Inc R cons/R V1.	Vd.
1	7	24	212	296	.72	200	345	.58	212	345	.62	---	150	150	---
1	8	21	162	424	.38	236	410	.58	162	410	.40	---	438	286	---
1	9	21	130	278	.47	180	275	.66	130	275	.47	---	282	282	---
1	Mean	22	168	332	.51	206	343	.60	168	343	.49	---	290	239	---
3	7	26	168	356	.47	168	356	.47	168	356	.47	---	---	---	---
3	8	23	254	382	.66	298	428	.70	254	428	.59	---	338	330	---
3	9	23	104	312	.33	104	308	.34	104	308	.34	---	325	---	---
3	Mean	24	175	350	.50	190	364	.52	175	364	.48	---	331	330	---
2-3	1	28.5	194	490	.40	194	485	.40	194	485	.40	---	505	---	---
2-3	2	28.5	284	521	.54	232	485	.48	226	495	.46	455	600	240	455
2-3	3	27	160	318	.50	160	318	.50	160	318	.50	---	---	---	---
2-3	4	26.5	191	246	.78	218	---	---	191	---	---	---	246	246	---
2-3	5	28.5	190	260	.73	227	238	.96	190	238	.80	---	282	282	---
2-3	6	28.5	202	486	.42	202	486	.42	202	486	.42	---	---	---	---
2-3	Mean	28	204	386	.53	206	402	.51	194	404	.48	455	408	256	455
4-5	1	30.5	268	238	1.13	225	238	.95	225	238	.95	310	---	---	---
4-5	2	30.5	198	305	.65	198	305	.65	198	305	.65	---	---	---	---
4-5	3	28.5	234	392	.60	234	392	.60	234	392	.60	---	---	---	---
4-5	4	28.5	138	301	.46	138	301	.46	138	301	.46	---	---	---	---
4-5	5	30.5	155	210	.74	155	210	.74	155	210	.74	---	---	---	---
4-5	6	30.5	231	375	.62	231	375	.62	231	375	.62	---	---	---	---
4-5	Mean	30	204	304	.67	196	304	.65	196	304	.65	310	---	---	---
6-8	1	33	240	453	.53	198	453	.44	198	453	.44	282	---	---	---
6-8	2	33	242	376	.64	241	375	.64	242	376	.64	---	---	---	---
6-8	3	31	174	424	.41	174	424	.41	174	424	.41	---	---	---	---
6-8	4	31	206	353	.58	206	353	.58	206	353	.58	---	---	---	---
6-8	5	33	240	440	.54	240	438	.55	240	440	.54	---	---	---	425
6-8	6	33	165	404	.41	165	404	.41	165	404	.41	---	---	---	---
6-8	Mean	32	211	408	.52	204	408	.50	204	408	.50	282	---	---	425
	Parent No.														
1-3	7								186	397	.47				
1-3	8								225	380	.59				
1-3	9								192	308	.63				
1-3	1								159	230	.69				
1-3	2								168	250	.67				
1-3	3								180	302	.60				
1-3	4								185	265	.70				
1-3	5								176	270	.65				
1-3	6								168	294	.57				
1-3	Mean								182	300	.60				

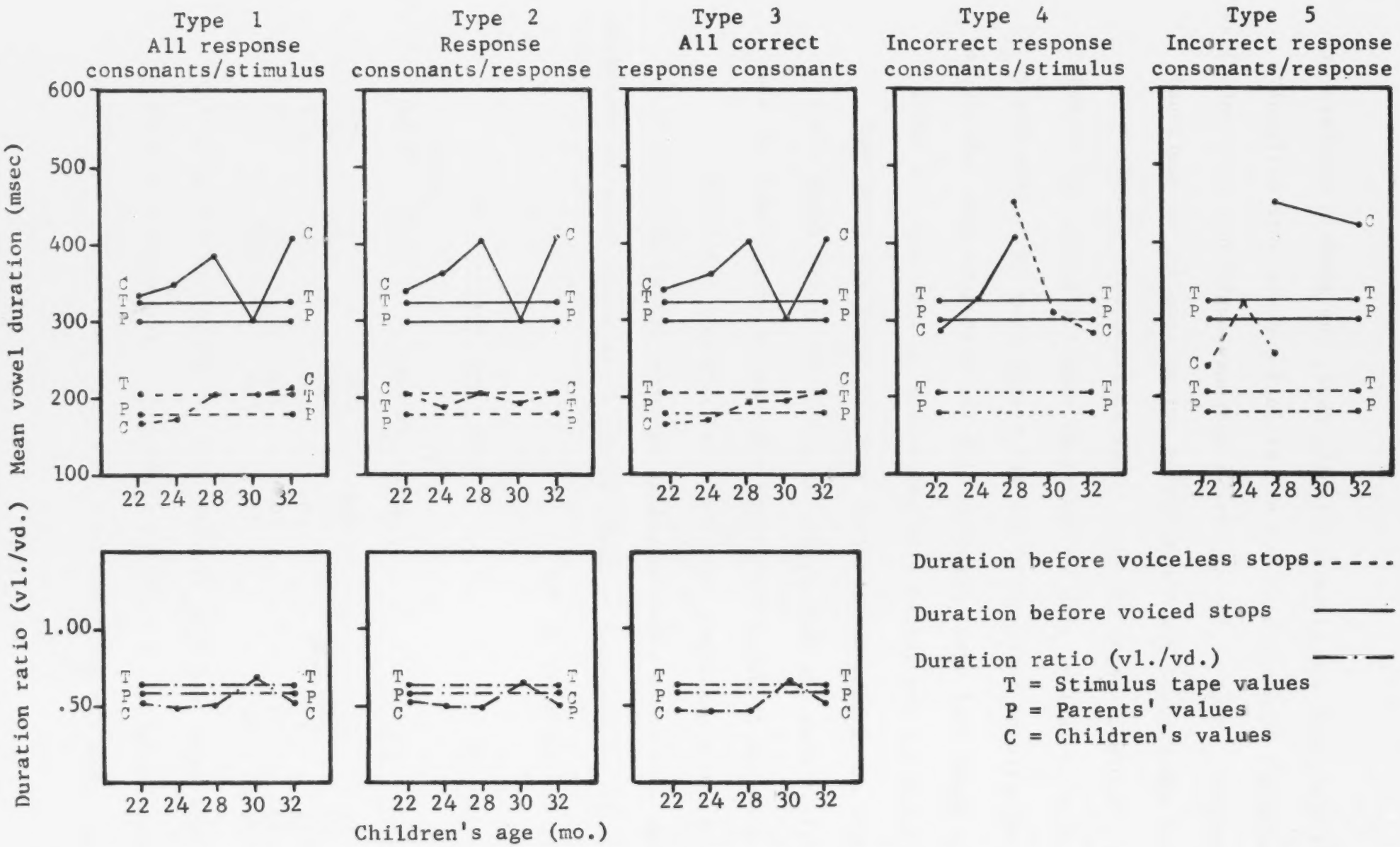

Fig. 15 Second study, children's responses to taped stimuli of normal duration. Mean vowel duration and duration ratio for /i/ before stops in /fit/, /sid/, as a function of children's age.

stimuli than with the picture stimuli, thus, the graphic displays of the incorrect response data are not as full and are more difficult to interpret. Most of the incorrect response consonants were voiceless stop /t/ substituted for the stimulus voiced stop /d/ as mentioned above. Figure 16 shows the mean vowel duration with voiceless stops used correctly, with voiced stops used correctly, and voiceless stops substituted incorrectly for the voiced stop /d/. This figure clearly shows that vowel duration with the voiceless stop substituted incorrectly for the voiced stop was closer to that with the voiced stop used correctly, than to that with the voiceless stop used correctly. Thus, in this study, as was found in the first study, vowel duration produced with stops was usually appropriate for the final stimulus consonant, not the final response consonant.

The mean vowel duration values produced by the children in this study are compared to those in the first study (scoring procedure type 1) in the table below:

Mean Age (mo.)		Mean vowel duration (msec)			
		/fit/		/sid/	
Tape	Picture	Tape	Picture	Tape	Picture
22	22	168	180	332	346
24	24	175	306	350	464
28	27	204	240	386	371
30	30	204	191	304	354
32	34	211	269	408	424

This table and Fig. 17 show that the durations were not very different under the 2 stimulus conditions. It can also be seen, however, that the durations were much more consistent (especially

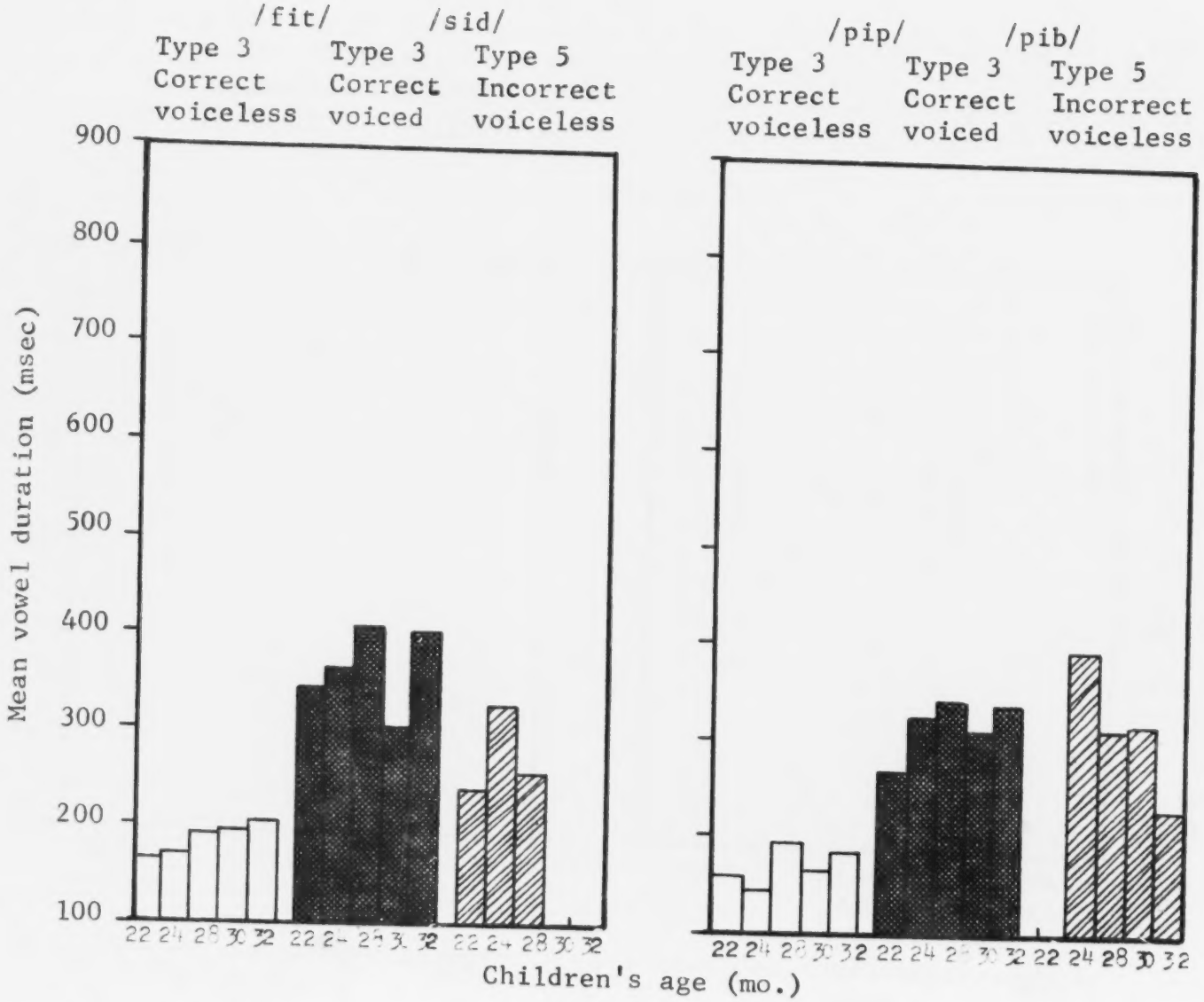

Fig. 16 Second study, children's responses to taped stimuli of normal duration. Mean vowel duration for /i/ before correctly used voiceless and voiced stops and before voiceless stops substituted for voiced stops, as a function of children's age.

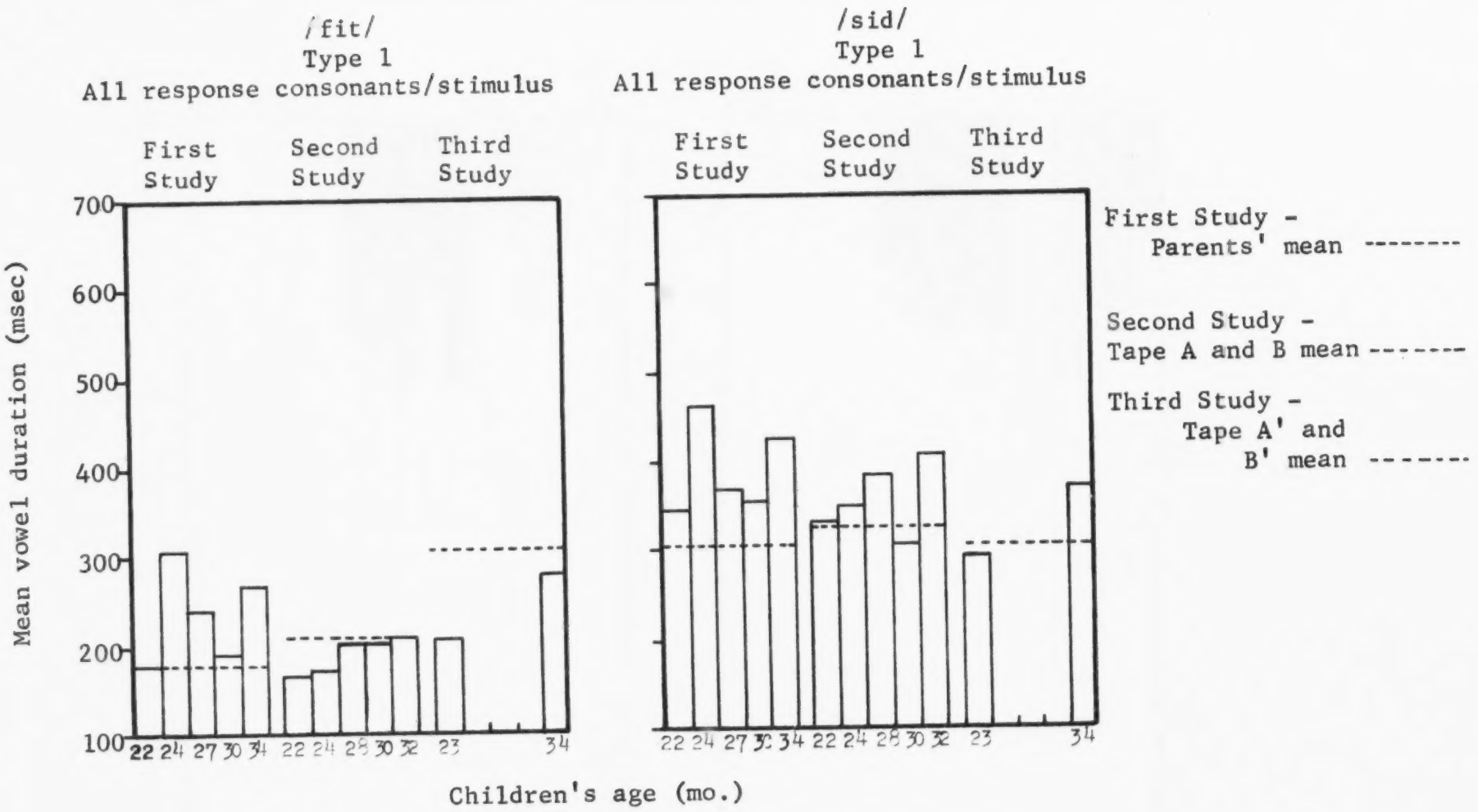

Fig. 17 First study, children's responses to picture stimuli, Second study, children's responses to taped stimuli of normal duration and Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration for /i/ before stops in /fit/, /sid/, as a function of children's age.

before voiceless stop) with the tape stimuli study than with the picture stimuli study, although correct differential vowel duration was maintained in both studies from the mean age of 22 months.

Final stops after /i/ in constant /#p--/ words. As mentioned above, the statistical analysis showed no significant difference in these words from the story words. Table 14 shows there were no errors for final voiceless stop /p/. It also shows about the same error rate for the final voiced stop /b/ as for the final voiced stop /d/ from the story words. Scoring procedure types 1, 2, 3, 4 and 5 in Table 16 and Fig. 18 show a pattern similar to that for the story words. Comparison of scoring procedure type 5 to Type 3 on Fig. 17 shows that here, also, the vowel duration used with voiceless stops incorrectly substituted for voiced stops was closer to that for correctly used voiced stops than voiceless stops.

Vowel duration in relation to voicing of final fricatives

Final fricatives after /i/ in story words. Table 17 lists the incorrect final response consonants substituted in /tiθ/ and /piz/. A comparison of the percentage of these final response consonants for the story words and those in the first study is given in the table below:

Table 16

Second study, children's responses to taped stimuli of normal duration. Mean vowel duration (msec) for /i/ before stops in /pip/, /pib/, as a function of children's age

Stim. tape: Vl. st. /pip/ 192, Vd. st. /pib/ 325, Vl./Vd. Ratio .59

Sess. No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
1	7	24	155	251	.62	155	251	.62	155	251	.62	---	---	---	---
1	8	21	204	404	.50	204	355	.57	204	355	.57	---	420	---	---
1	9	21	121	214	.57	121	200	.61	121	200	.61	---	255	---	---
1	Mean	22	160	290	.55	160	268	.60	160	268	.60	---	338	---	---
3	7	26	176	370	.48	176	370	.48	176	370	.48	---	---	---	---
3	8	23	182	378	.48	275	320	.86	182	320	.57	---	398	398	---
3	9	23	80	285	.28	80	285	.28	80	285	.28	---	---	---	---
3	Mean	24	146	344	.42	177	325	.54	146	325	.45	---	398	398	---
2-3	1	28.5	245	298	.82	245	298	.82	245	298	.82	---	---	---	---
2-3	2	28.5	211	510	.41	246	508	.48	211	508	.42	---	512	385	---
2-3	3	27	202	290	.70	202	290	.70	202	290	.70	---	---	---	---
2-3	4	26.5	121	185	.66	153	---	---	121	---	---	---	185	185	---
2-3	5	28.5	172	282	.61	222	252	.88	172	252	.68	---	375	375	---
2-3	6	28.5	225	308	.73	225	308	.73	225	308	.73	---	---	---	---
2-3	Mean	28	196	312	.63	216	331	.65	196	331	.59	---	358	315	---
4-5	1	30.5	182	325	.56	182	325	.56	182	325	.56	---	---	---	---
4-5	2	30.5	194	350	.55	194	350	.55	194	350	.55	---	---	---	---
4-5	3	28.5	166	445	.37	166	392	.42	166	392	.42	---	605	---	---
4-5	4	28.5	145	264	.55	203	208	.98	145	208	.70	---	320	320	---
4-5	5	30.5	120	246	.49	120	246	.49	120	246	.49	---	---	---	---
4-5	6	30.5	175	346	.51	175	346	.51	175	346	.51	---	---	---	---
4-5	Mean	30	164	329	.50	174	311	.56	164	311	.53	---	462	320	---
6-8	1	33	242	438	.55	242	438	.55	242	438	.55	---	---	---	---
6-8	2	33	234	325	.72	234	345	.68	234	345	.68	---	230	230	---
6-8	3	31	138	333	.41	138	333	.41	138	333	.41	---	---	---	---
6-8	4	31	148	219	.67	148	219	.67	148	219	.67	---	---	---	---
6-8	5	33	202	374	.54	202	374	.54	202	374	.54	---	---	---	---
6-8	6	33	144	322	.45	144	322	.45	144	322	.45	---	---	---	---
6-8	Mean	32	184	336	.55	184	338	.55	184	338	.55	---	230	230	---
	Parent No.														
1-3	7								172	390	.44				
1-3	8								212	372	.57				
1-3	9								194	296	.65				
1-3	1								123	222	.55				
1-3	2								172	286	.60				
1-3	3								173	300	.58				
1-3	4								142	238	.60				
1-3	5								153	219	.70				
1-3	6								166	258	.64				
1-3	Mean								167	286	.58				

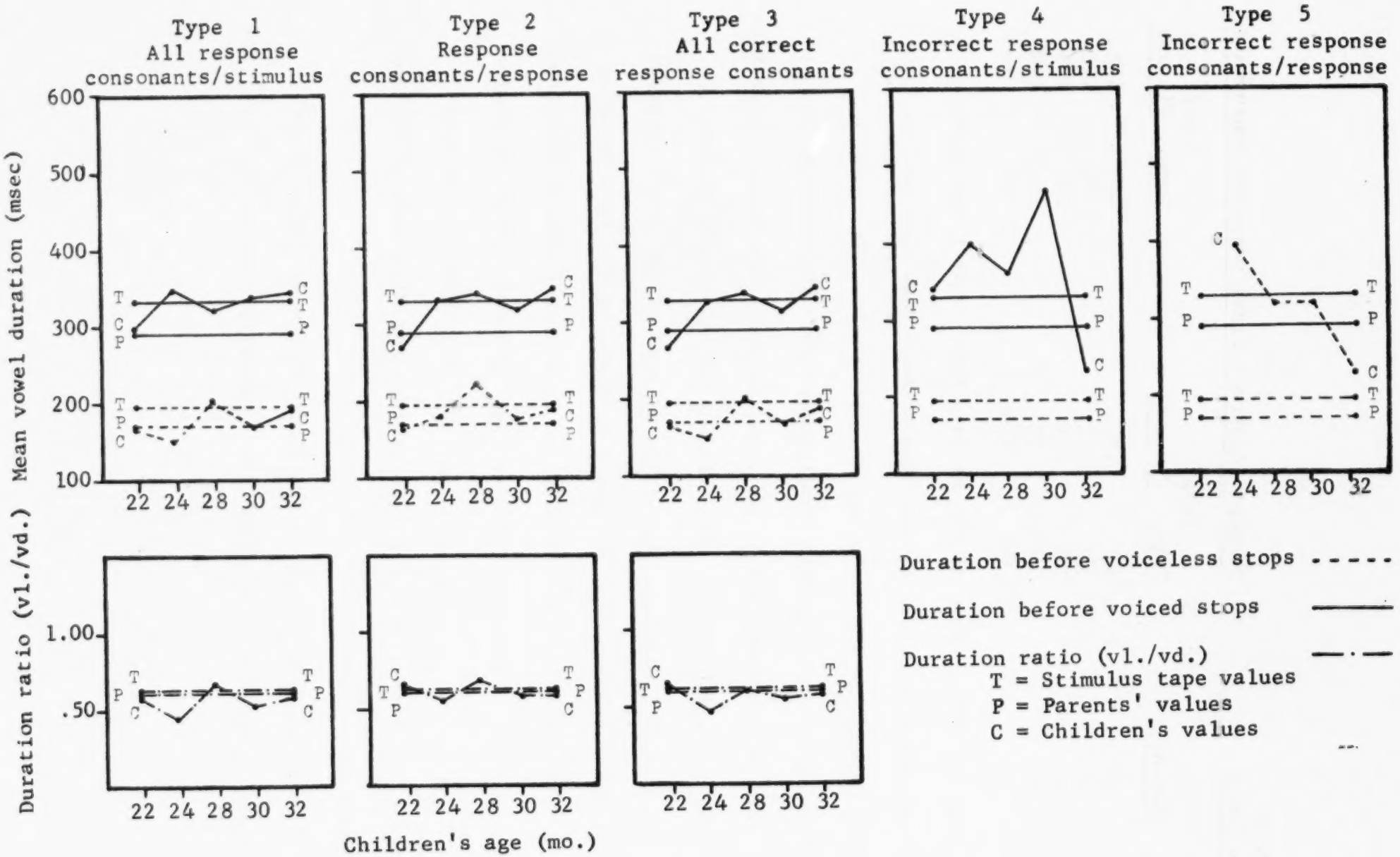

Fig. 18 Second study, children's responses to taped stimuli of normal duration. Mean vowel duration and duration ratio for /i/ before stops in /pip/, /pib/, as a function of children's age.

Mean Age (mo.)		Percent incorrect final response consonants			
		/tiθ/		/piz/	
Tape	Picture	Tape	Picture	Tape	Picture
22	22	33%	33%	41%	41%
24	24	33%	33%	8%	41%
28	27	16%	19%	25%	30%
30	30	4%	5%	16%	11%
32	34	0%	0%	8%	4%

From the above table it can be seen that in most age groups there were fewer errors with the tape stimuli than with the picture stimuli; exceptions are at 30 and 32 (34) months. There was a decreasing error rate in both conditions. The substitutions in this study were of the same variety as found in the first study - primarily voiceless fricative /s/ for the stimulus voiced fricative /z/.

Despite the incorrect production of some of the final response consonants, scoring procedure type 1 on Table 18 and Fig. 19 shows correct differential vowel duration to have been produced throughout all age groups. The voiceless-to-voiced ratio was .61 at 22 months and .52 at 32 months. The stimulus tape ratio was .51 and that for the parents was .54. The same pattern was also seen in scoring procedure types 2 and 3.

Scoring procedure types 4 and 5 are listed in Table 18 and displayed on Fig. 19. They show the same pattern which the incorrect

Table 17
Second study, children's responses to taped stimuli of normal duration.
Incorrect response consonants and missing responses
for /i/ before fricatives

Sess. No.	Mean Age(mo.)		/tiθ/ Vl.fr.	/piz/ Vd.fr.	/pis/ Vl.fr.	/piz/ Vd.fr.
1	22	Inc. resp. cons.	4/t/	5/s/	0	2/s/ 1/dz/
		No. inc. resp.	4	5	0	3
		% inc. resp.	33%	41%	0%	25%
		No. missing resp.	0	0	0	0
		% missing resp.	0%	0%	0%	0%
3	24	Inc. resp. cons.	4/t/	1/s/	0	2/s/ 1/sts/
		No. inc. resp.	4	1	0	3
		% inc. resp.	33%	8%	0%	25%
		No. missing resp.	0	0	0	0
		% missing resp.	0%	0%	0%	0%
2-3	28	Inc. resp. cons.	2/t/ 1/tʃ/ 1/ts/	3/s/ 2/θ/ 1/ts/	1/z/ 1/θ/ 1/ts/ 1/dz/	2/tʃ/ 1/s/ 1/dz/ 1/bz/
		No. inc. resp.	4	6	4	5
		% inc. resp.	16%	25%	16%	20%
		No. missing resp.	3	2	2	3
		% missing resp.	12%	8%	8%	12%
4-5	30	Inc. resp. cons.	1/z/	2/s/ 2/θ/	2/θ/ 1/ts/	1/θ/
		No. inc. resp.	1	4	3	1
		% inc. resp.	4%	16%	12%	4%
		No. missing resp.	0	1	0	0
		% missing resp.	0%	0%	0%	0%
6-8	32	Inc. resp. cons.	0	2/θ/ 1/d/	1/z/	0
		No. inc. resp.	0	3	1	0
		% inc. resp.	0%	8%	2%	0%
		No. missing resp.	0	0	0	0
		% missing resp.	0%	0%	0%	0%

Table 18

Second study, children's responses to taped stimuli of normal duration. Mean vowel duration (msec) for /i/ before fricatives in /tiθ/, /piz/, as a function of children's age

Stim. tape: V1. fr. /tiθ/ 205, Vd. fr. /piz/ 400, V1./Vd. Ratio .51

Sess. No.	Child No.	Age (mo)	Type 1 All resp. cons/stim V1.	Vd.	Rat.	Type 2 Response cons/resp V1.	Vd.	Rat.	Type 3 All correct resp cons V1.	Vd.	Rat.	Type 4 Inc R cons/S V1.	Vd.	Type 5 Inc R cons/R V1.	Vd.
1	7	24	231	331	.70	231	331	.70	231	331	.70	---	---	---	---
1	8	21	210	475	.44	372	578	.65	---	578	---	210	372	372	---
1	9	21	321	442	.73	357	555	.64	321	555	.58	---	405	405	---
1	Mean	22	254	416	.61	320	488	.66	276	488	.57	210	388	388	---
3	7	26	180	470	.38	180	470	.38	180	470	.38	---	---	---	---
3	8	23	311	668	.47	610	688	.89	---	688	---	311	610	610	---
3	9	23	311	445	.70	311	445	.70	311	445	.70	---	---	---	---
3	Mean	24	268	528	.51	367	534	.69	246	534	.46	311	610	610	---
2-3	1	28.5	315	468	.67	315	445	.71	315	415	.76	---	520	---	505
2-3	2	28.5	261	590	.44	282	590	.48	282	590	.48	240	---	---	---
2-3	3	27	188	480	.39	188	480	.39	188	480	.39	---	---	---	---
2-3	4	26.5	156	250	.63	229	---	---	165	---	---	148	250	272	---
2-3	5	28.5	308	315	.98	308	315	.98	308	315	.98	---	---	---	---
2-3	6	28.5	382	602	.63	382	602	.63	382	602	.63	---	---	---	---
2-3	Mean	28	268	450	.59	284	486	.58	273	480	.57	194	385	272	505
4-5	1	30.5	340	415	.82	340	415	.82	340	415	.82	---	---	---	---
4-5	2	30.5	295	334	.88	268	342	.78	268	334	.80	375	---	---	375
4-5	3	28.5	320	561	.57	320	565	.57	320	565	.57	---	558	---	---
4-5	4	28.5	255	350	.73	285	332	.86	255	332	.77	---	405	405	---
4-5	5	30.5	196	308	.64	196	308	.64	196	308	.64	---	---	---	---
4-5	6	30.5	241	454	.53	248	513	.48	241	513	.47	---	275	275	---
4-5	Mean	30	274	404	.68	276	412	.67	270	411	.66	375	412	340	375
6-8	1	33	319	576	.55	319	586	.54	319	586	.54	---	558	---	---
6-8	2	33	220	338	.65	220	338	.65	220	338	.65	---	---	---	---
6-8	3	31	182	490	.37	182	490	.37	182	490	.37	---	---	---	---
6-8	4	31	223	384	.58	223	384	.58	223	384	.58	---	---	---	---
6-8	5	33	272	568	.48	272	596	.46	272	596	.46	---	425	---	---
6-8	6	33	240	456	.53	240	456	.53	240	456	.53	---	---	---	---
6-8	Mean	32	242	468	.52	242	475	.51	242	475	.51	---	491	---	---
	Parent No.														
1-3	7								255	549	.46				
1-3	8								252	416	.61				
1-3	9								224	420	.53				
1-3	1								209	320	.65				
1-3	2								209	355	.59				
1-3	3								212	430	.49				
1-3	4								202	362	.56				
1-3	5								196	388	.51				
1-3	6								213	364	.59				
1-3	Mean								219	400	.54				

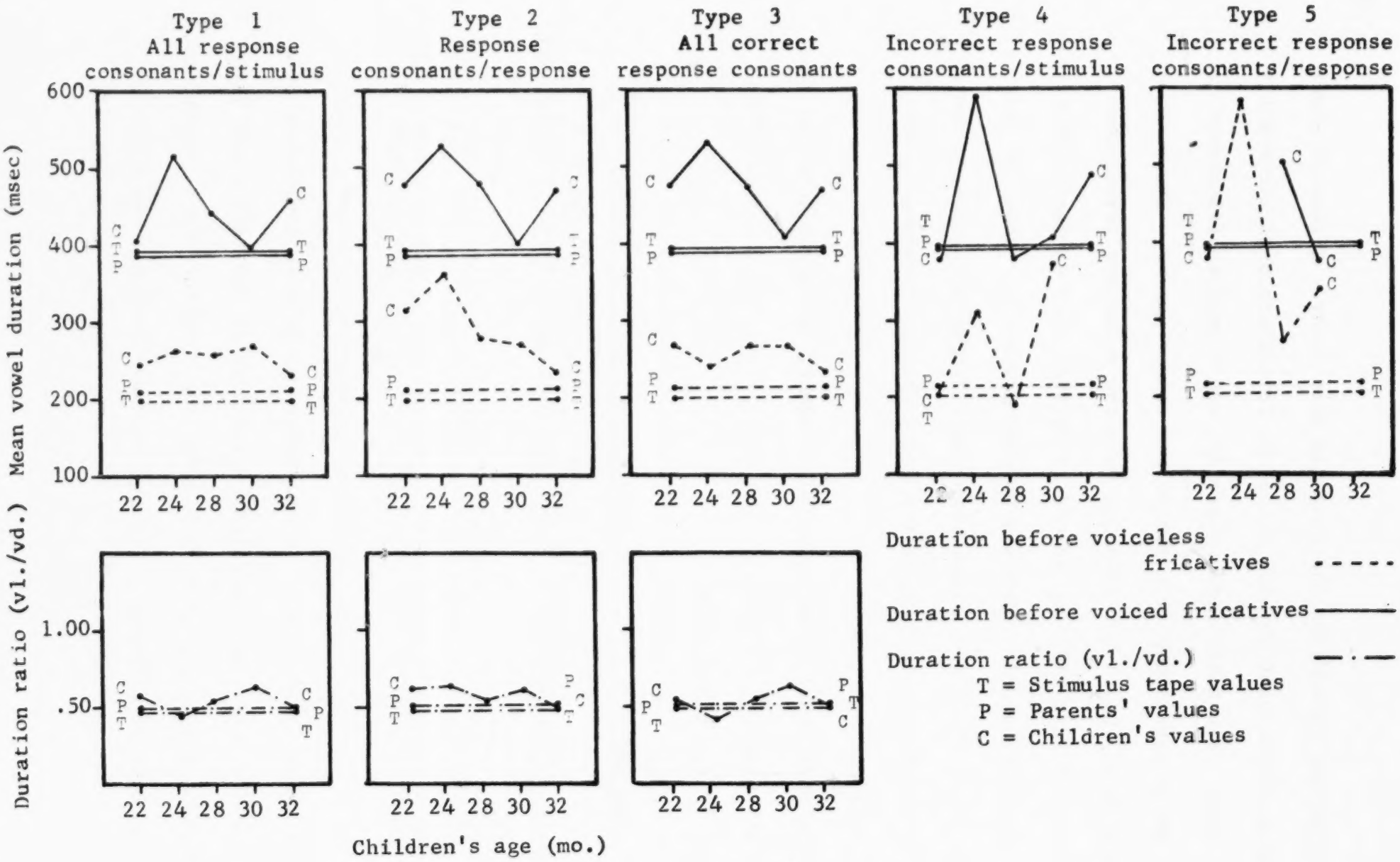

Fig. 19 Second study, children's responses to taped stimuli of normal duration. Mean vowel duration and duration ratio for /i/ before fricatives in /tiθ/, /piz/, as a function of children's age.

substitutions showed for the stops in this study. Figure 20 shows the mean vowel duration with voiceless fricatives used incorrectly with voiced fricatives used correctly, and voiceless fricatives incorrectly substituted for the voiced fricative /z/. The figure clearly shows that vowel duration with the voiceless fricatives is closer to that with the voiced fricatives used correctly than to that with the voiceless fricatives used correctly. Thus, in this study, as in the first study, vowel duration with fricatives was usually produced according to the final stimulus consonant, not the final response consonant.

The mean vowel duration values produced by the children in this study are compared to those in the first study (scoring procedure type 1) in the table below:

Mean Age (mo.)		Mean vowel duration (msec)					
		/tiθ/			/piz/		
Tape	Picture	Tape	Picture	Dif.	Tape	Picture	Dif.
22	22	254	225	29	416	430	14
24	24	268	262	6	528	456	72
28	27	268	308	40	450	475	25
30	30	274	290	16	404	459	55
32	34	242	210	32	468	497	29

The difference in the durations between the tape and picture studies is not very great. There appears to be more consistency in the duration before the voiceless fricatives in the tape study than the picture study, and they were about the same for the 2 conditions for the voiced fricatives. Figure 21 shows this on a bar graph.

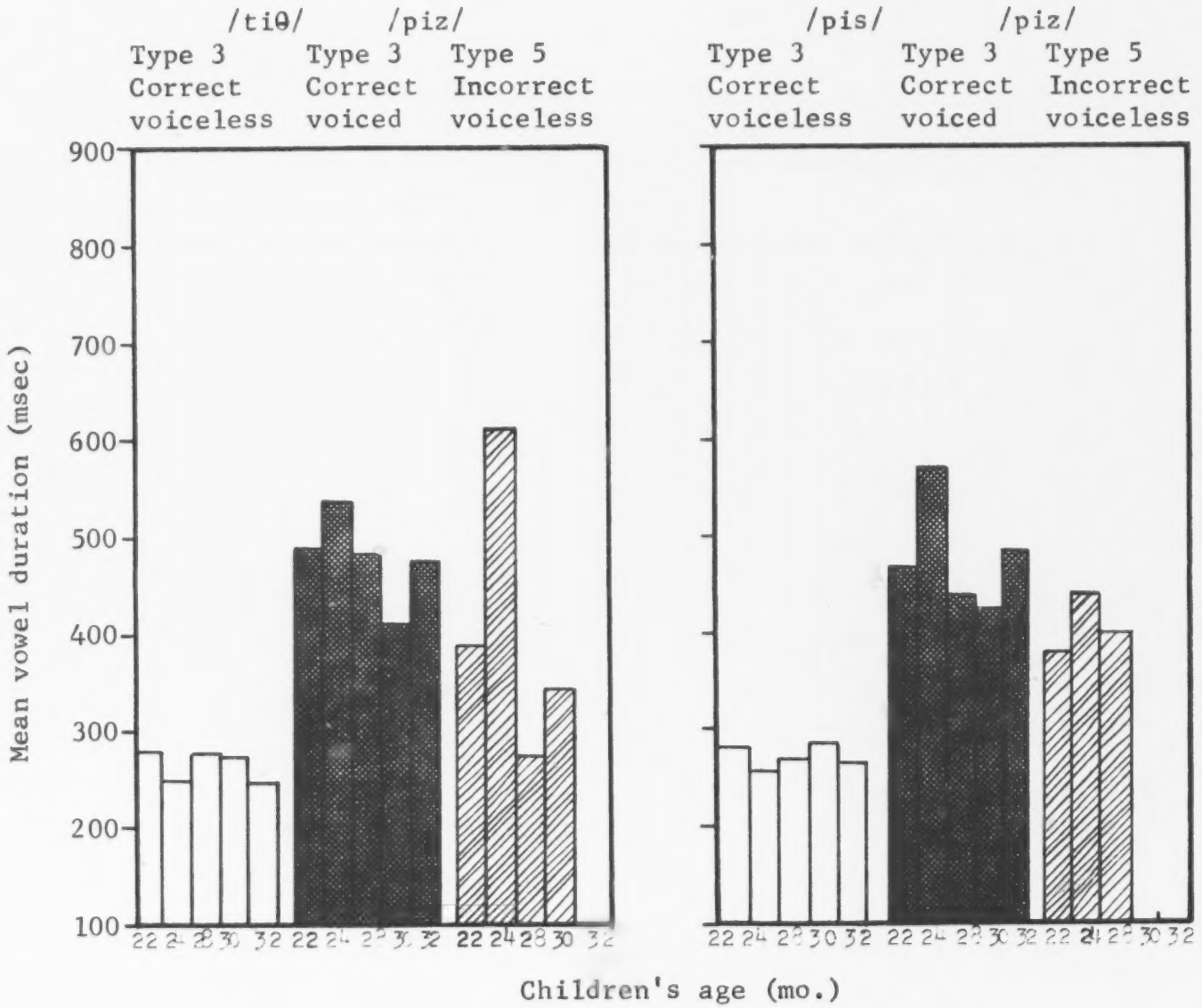

Fig. 20 Second study, children's responses to taped stimuli of normal duration. Mean vowel duration for /i/ before correctly used voiceless and voiced fricatives and before voiceless fricatives substituted for voiced fricatives, as a function of children's age.

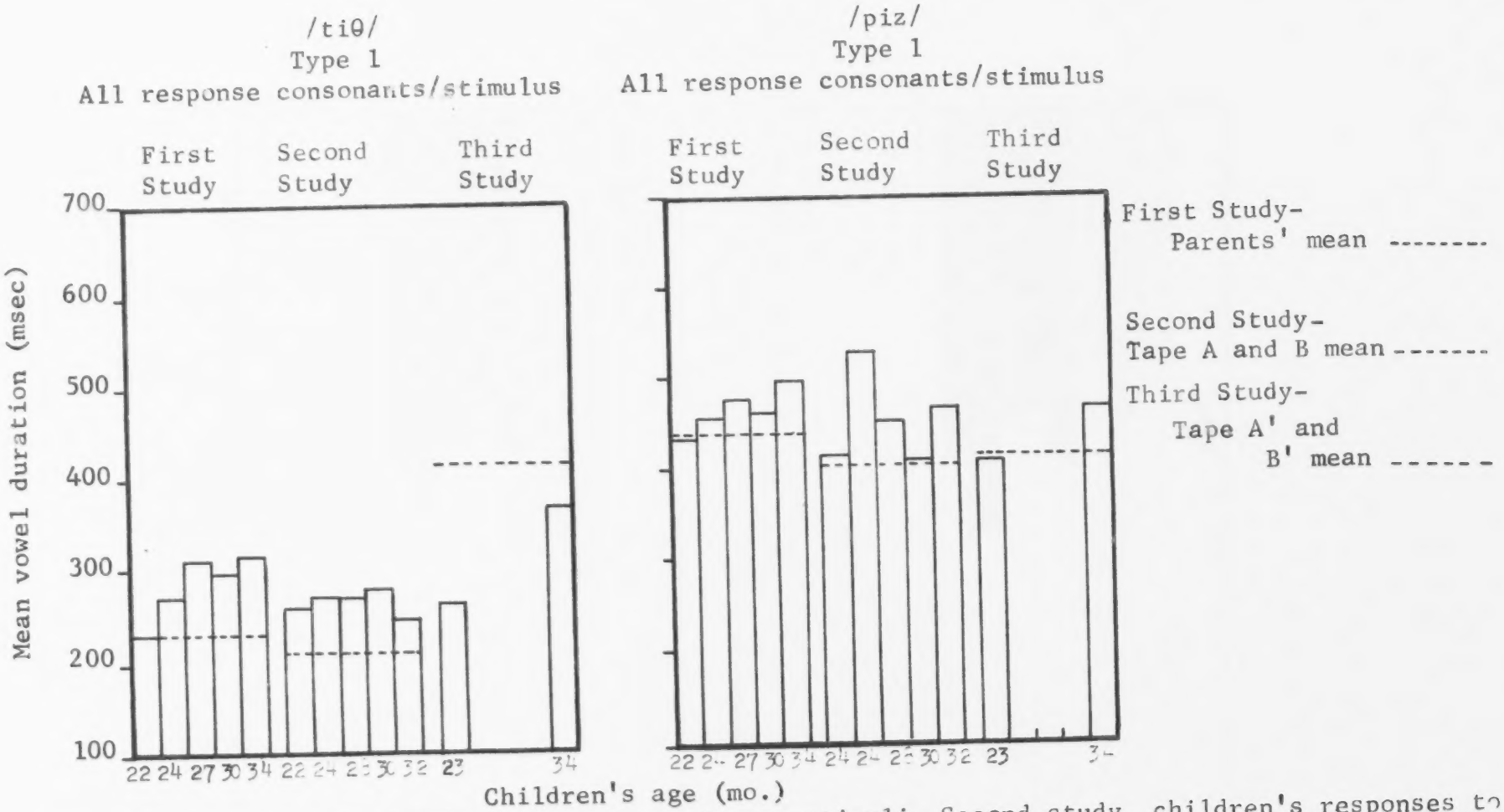

Fig. 21 First study, children's responses to picture stimuli, Second study, children's responses to taped stimuli of normal duration and Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration for /i/ before fricatives in /tiθ/, /piz/, as a function of children's age.

Final fricatives after /i/ in constant /#p--/ words. Table 17 shows there were some errors for the voiceless fricative /s/ at 28, 30, and 32 months, but none earlier. Most of the errors were for the voiced fricative /z/ and these were of the same nature as those for the voiced fricative /z/ in the story words (the actual CVC word was the same). The most common substitution was the voiceless fricative /s/. Scoring procedure types 1, 2, 3, 4 and 5 in Table 19 and Fig. 22 show a pattern similar to that for the story words. Scoring procedure type 5 is compared to Type 3 on Fig. 20 and it shows that here also, the vowel duration used with voiceless fricatives incorrectly substituted for the voiced fricative was closer in duration to that for correctly used voiced fricatives than voiceless fricatives.

Vowel duration in relation to manner of articulation of final consonants

Final stops and fricatives in story words. Tables 14 and 17 show the errors produced for stops and fricatives; these have been discussed under Questions 1 and 2. The manner of production, stop, was never confused with the manner of producton, fricative, as was the case for voicing.

Table 19

Second study, children's responses to taped stimuli of normal duration. Mean vowel duration (msec) for /i/ before fricatives in /pis/, /piz/, as a function of children's age

Stim. tape: Vl. fr. /pis/ 225, Vd. fr. /piz/ 455, Vl/Vd. Ratio .49

Sess. No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
1	7	24	220	392	.56	220	415	.53	220	415	.53	---	325	---	---
1	8	21	332	485	.66	334	520	.64	322	520	.62	---	380	380	---
1	9	21	295	443	.66	312	465	.67	295	465	.63	---	380	380	---
1	Mean	22	279	440	.63	288	466	.62	279	466	.60	---	361	380	---
3	7	26	201	480	.42	201	480	.42	201	480	.42	---	---	---	---
3	8	23	320	500	.64	371	680	.55	320	680	.47	---	440	440	---
3	9	23	238	551	.43	238	551	.43	238	551	.43	---	---	---	---
3	Mean	24	253	510	.50	270	570	.47	253	570	.44	---	440	440	---
2-3	1	28.5	240	431	.56	258	431	.60	258	431	.60	185	---	---	---
2-3	2	28.5	448	561	.80	522	549	.95	462	561	.82	432	---	640	500
2-3	3	27	128	438	.29	128	438	.29	128	438	.29	---	---	---	---
2-3	4	26.5	170	205	.83	178	320	.56	183	320	.57	130	166	165	---
2-3	5	28.5	225	332	.68	225	386	.58	225	386	.58	---	170	---	---
2-3	6	28.5	342	610	.56	342	502	.68	342	502	.68	---	825	---	---
2-3	Mean	28	258	430	.60	276	438	.63	266	440	.61	249	387	402	500
4-5	1	30.5	280	462	.61	280	400	.70	280	400	.70	---	525	---	---
4-5	2	30.5	314	410	.77	314	410	.77	314	410	.77	---	---	---	---
4-5	3	28.5	481	541	.89	515	610	.84	515	610	.84	470	335	---	---
4-5	4	28.5	202	415	.49	202	415	.49	202	415	.49	---	---	---	---
4-5	5	30.5	172	364	.47	172	364	.47	172	364	.47	---	---	---	---
4-5	6	30.5	210	350	.60	210	350	.60	210	350	.60	---	---	---	---
4-5	Mean	30	276	424	.65	282	424	.66	282	424	.66	470	430	---	---
6-8	1	33	358	704	.51	358	704	.51	358	704	.51	---	---	---	---
6-8	2	33	286	328	.88	288	320	.90	288	328	.88	280	---	---	280
6-8	3	31	240	505	.48	240	505	.48	240	505	.48	---	---	---	---
6-8	4	31	198	370	.53	198	370	.53	198	370	.53	---	---	---	---
6-8	5	33	322	509	.63	322	509	.63	322	509	.63	---	---	---	---
6-8	6	33	174	472	.37	174	472	.37	174	472	.37	---	---	---	---
6-8	Mean	32	263	482	.55	264	480	.55	264	482	.55	280	---	---	280
	Parent No.														
1-3	7								220	558	.40				
1-3	8								246	434	.57				
1-3	9								232	420	.55				
1-3	1								200	312	.64				
1-3	2								219	368	.60				
1-3	3								211	459	.46				
1-3	4								205	372	.55				
1-3	5								189	376	.50				
1-3	6								182	425	.43				
1-3	Mean								212	414	.51				

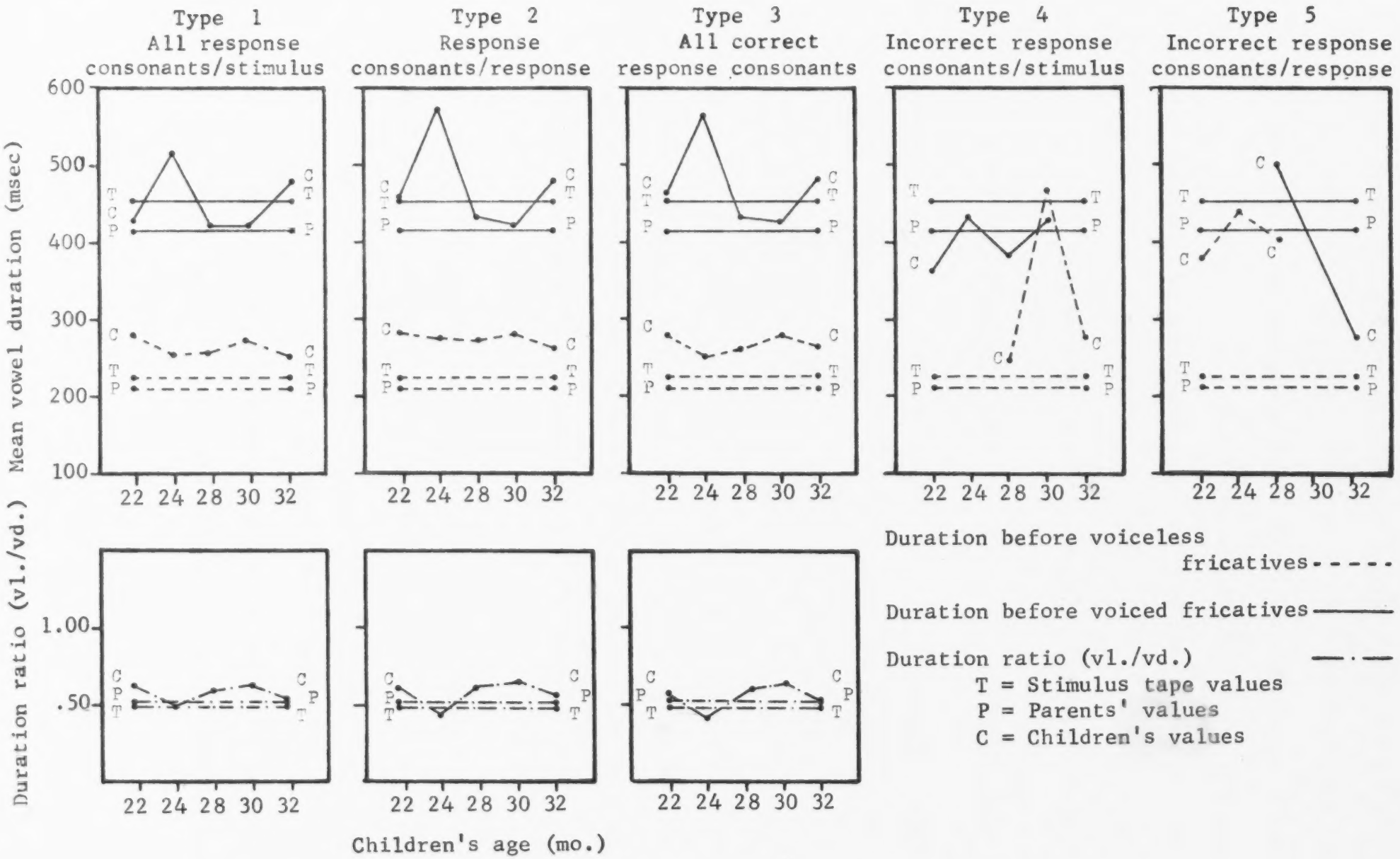

Fig. 22 Second study, children's responses to taped stimuli of normal duration. Mean vowel duration and duration ratio for /i/ before fricatives in /pis/, /piz/, as a function of children's age.

Scoring procedure type 1 on Table 20 and Fig. 23 shows that correct differential vowel duration was produced with stops vs. fricatives continuously from 22 to 32 months of age. The same was true for scoring procedure types 2 and 3.

The mean vowel duration values produced by the children before stops and fricatives in this study are compared to those in the first study (scoring procedure type 1) in the table below:

Mean Age (mo.)		Mean vowel duration (msec)			
		Stops		Fricatives	
Tape	Picture	Tape	Picture	Tape	Picture
22	22	250	263	335	328
24	24	262	385	397	359
27	28	295	305	360	408
30	30	254	272	339	391
32	34	310	346	356	403

It can be seen from this table that vowel duration was always produced correctly with the tape stimuli, but this was not always the case with the picture stimuli (24 mo.) Thus, this is the single main difference between the vowel durations produced in the first and second studies.

Final stops and fricatives in constant /#p--/ words. Scoring procedure types 1, 2 and 3 in Table 21 and Fig. 24 show the same pattern as the story words.

SUMMARY

Correct differential vowel duration was seen to have already emerged at the youngest ages recorded with the tape stimuli - 21

Table 20

Second study, children's responses to taped stimuli of normal duration. Mean vowel duration (msec) for /i/ before stops and fricatives in the story words, as a function of children's age

Stim. tape: Stops 266, Fricatives 302

Sess. No.	Child No.	Age (mo)	Type 1 All resp. cons/stim St.	Type 1 All resp. cons/stim Fr.	Type 2 Response cons/resp St.	Type 2 Response cons/resp Fr.	Type 3 All correct resp cons St.	Type 3 All correct resp cons Fr.
1	7	24	254	281	272	281	278	281
1	8	21	293	342	323	475	286	578
1	9	21	204	382	228	456	202	438
1	Mean	22	250	335	274	404	256	382
3	7	26	262	325	262	325	262	325
3	8	23	318	490	362	649	340	688
3	9	23	208	378	206	378	206	378
3	Mean	24	262	397	277	450	270	390
2-3	1	28.5	342	391	339	380	339	365
2-3	2	28.5	402	425	359	436	360	436
2-3	3	27	238	334	238	334	238	334
2-3	4	26.5	218	203	218	229	191	165
2-3	5	28.5	225	311	232	311	214	311
2-3	6	28.5	344	492	344	492	344	492
2-3	Mean	28	295	360	304	385	299	376
4-5	1	30.5	252	378	231	378	231	378
4-5	2	30.5	251	314	251	305	251	301
4-5	3	28.5	313	440	313	442	313	442
4-5	4	28.5	219	302	219	308	219	293
4-5	5	30.5	182	252	182	252	182	252
4-5	6	30.5	303	348	303	380	303	377
4-5	Mean	30	254	339	250	344	250	340
6-8	1	33	346	448	326	452	325	452
6-8	2	33	308	279	308	279	308	279
6-8	3	31	299	336	299	336	299	336
6-8	4	31	280	304	280	304	280	304
6-8	5	33	340	420	339	434	340	434
6-8	6	33	284	348	284	348	284	348
6-8	Mean	32	310	356	306	359	306	359
	Parent No.							
1-3	7						292	402
1-3	8						302	334
1-3	9						250	322
1-3	1						195	265
1-3	2						209	282
1-3	3						241	322
1-3	4						225	282
1-3	5						222	292
1-3	6						231	288
1-3	Mean						240	310

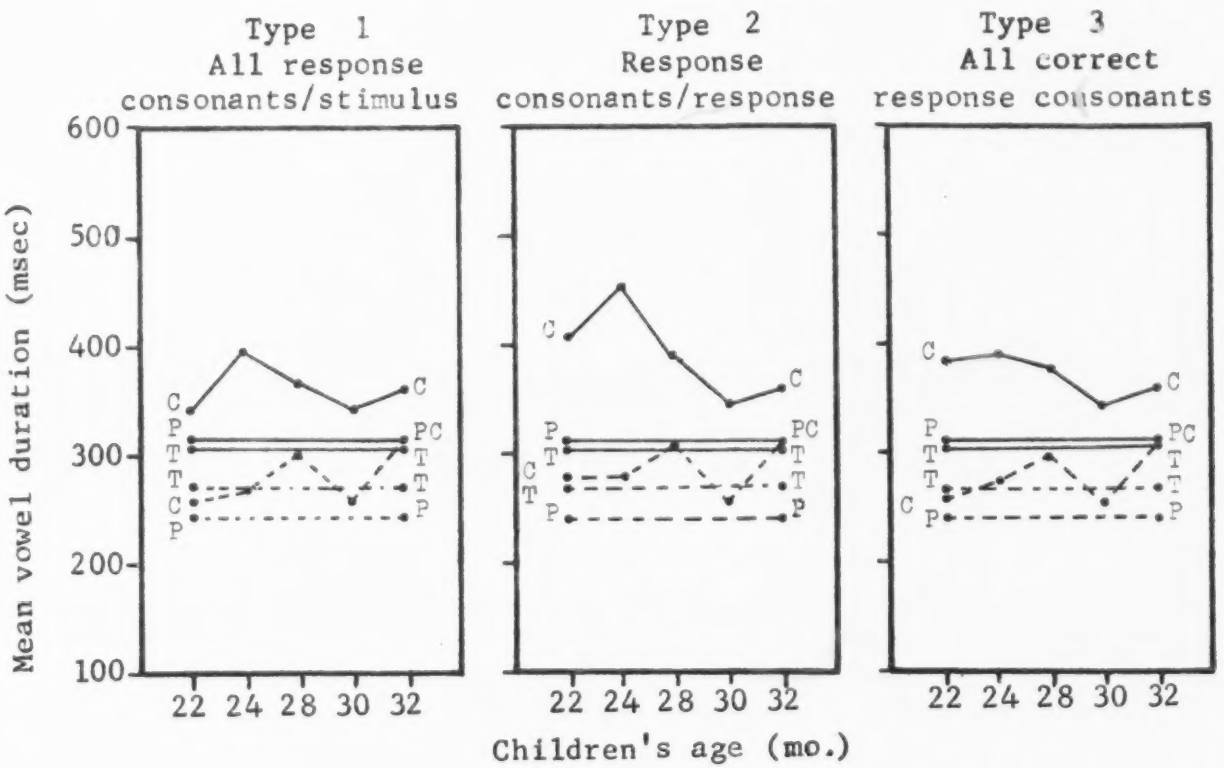

Fig 23 Second study, children's responses to taped stimuli of normal duration. Mean vowel duration for /i/ before stops and fricatives in the story words, as a function of children's age.

Table 21

Second study, children's responses to taped stimuli of normal duration. Mean vowel duration (msec) for /i/ before stops and fricatives in the constant /#p--/ words, as a function of children's age

Stim. tape: Stops 258, Fricatives 340

Sess. No.	Child No.	Age (mo)	Type 1 All resp. cons/stim St. Fr.	Type 2 Response cons/resp St. Fr.	Type 3 All correct resp cons St. Fr.
1	7	24	203 306	203 318	203 318
1	8	21	304 404	279 427	279 421
1	9	21	168 369	160 388	160 380
1	Mean	22	224 360	214 378	214 372
3	7	26	273 340	273 340	273 340
3	8	23	280 410	298 526	251 500
3	9	23	182 395	182 395	182 395
3	Mean	24	245 382	251 420	236 412
2-3	1	28.5	272 336	272 344	272 344
2-3	2	28.5	360 504	376 535	359 512
2-3	3	27	246 282	246 282	246 282
2-3	4	26.5	153 188	153 249	121 252
2-3	5	28.5	227 279	237 306	212 306
2-3	6	28.5	266 476	266 422	266 422
2-3	Mean	28	254 344	274 356	264 353
4-5	1	30.5	254 371	254 340	254 340
4-5	2	30.5	272 362	272 362	272 362
4-5	3	28.5	306 511	278 562	278 562
4-5	4	28.5	204 308	205 308	176 308
4-5	5	30.5	183 268	183 268	183 268
4-5	6	30.5	260 280	260 280	260 280
4-5	Mean	30	246 350	242 354	237 353
6-8	1	33	340 531	340 531	340 531
6-8	2	33	280 307	289 304	290 308
6-8	3	31	236 372	236 372	236 372
6-8	4	31	183 284	183 284	183 284
6-8	5	33	288 416	288 416	288 416
6-8	6	33	233 323	233 323	233 323
6-8	Mean	32	260 372	262 372	262 372
	Parent No.				
1-3	7				281 389
1-3	8				292 340
1-3	9				245 326
1-3	1				172 256
1-3	2				229 293
1-3	3				237 335
1-3	4				190 288
1-3	5				186 282
1-3	6				212 304
1-3	Mean				227 312

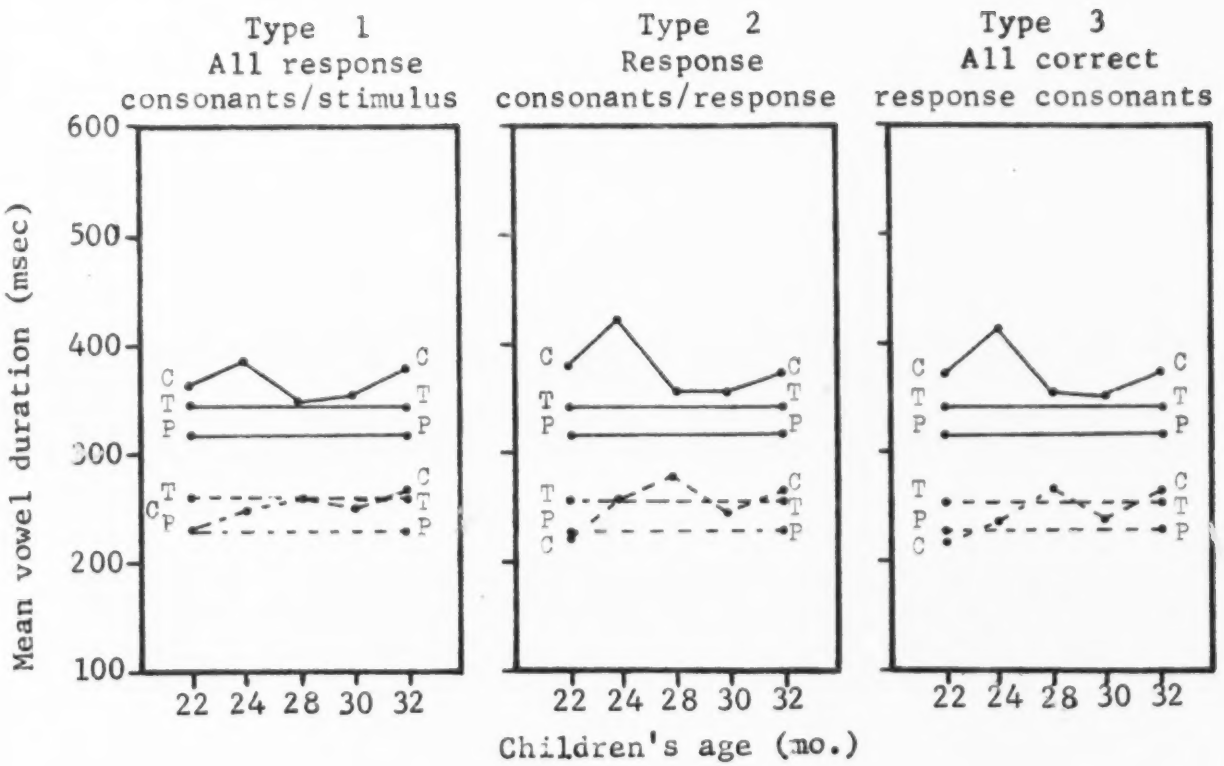

Fig. 24 Second study, children's responses to taped stimuli of normal duration. Mean vowel duration for /i/ before stops and fricatives in the constant /#p--/words, as a function of children's age.

months - just as with the picture stimuli. There were fewer final response consonant errors with the tape stimuli, however.

The statistical analysis showed there was no difference between the 2 word sets used in the tape - story words vs. constant /#p--/ words. The children always produced longer vowels before voiced than voiceless consonants, and longer vowels before fricatives than stops from the earliest ages on, in this study. The former was also true for responses produced in the first study, the latter was not.

Thus, because correct differential vowel duration was always produced as it should have been for American English (regardless of the nature of the final response consonant) for this study, and that statement could not be made for the responses in the first study, it is inferred that the children were probably imitating the vowel duration on the stimulus tape and not necessarily producing it according to the same internal model used in production of responses with only the picture stimuli. More about the possibility of direct imitation of tape stimuli was investigated in the third study.

FOOTNOTES (Chapter 3)

1. Robert E. Rudegeair

Chapter 4

THIRD STUDY: VOWEL DURATION IN CHILDREN'S RESPONSES ELICITED WITH TAPED STIMULI OF ABNORMAL EQUAL DURATION

INTRODUCTION

This study investigated the production of vowel duration in utterances elicited with a stimulus tape which had stimulus words of abnormal equal vowel durations. This was not a developmental study but rather a study which asked the questions: Given that the children were already producing correct differential vowel duration before voiced and voiceless consonants in utterances elicited with a story (no immediate model produced for them to copy) and that the children were also producing correct differential vowel duration in utterances elicited with a stimulus tape which had words with correct differential vowel durations (an immediate model produced for them to copy), what did the children do when presented with a stimulus tape which had words with abnormal equal vowel durations? Would the children continue to produce correct differential vowel duration, or would they follow the stimulus tape? The children in Group 1 were tested from 34 to 36 months of age; those in Group 2 were tested at 23 months of age.

METHOD

STIMULUS MATERIALS

The same stimulus words which were used in Stimulus Tapes A and B in the second study were used in the stimulus tapes in this study for Stimulus Tape A' and B'. The same speaker recorded the stimulus tapes using the same tape recording equipment. He recorded each word with several different durations, using a monotone, list intonation pattern. Vowel duration measurements for the stimulus words were taken from duplex oscillograms produced and segmented as described in Appendix B.

The utterances chosen for the stimulus tapes were then copied from this original tape. The vowel duration for /fit/ was chosen to match that for /sid/; the vowel duration for /tiθ/, matched that for /piz/; /pip/, /pib/; and /pis/, /piz/. Words were copied onto the tapes in the same order in which they occurred in the Stimulus Tapes A and B. For complete ordering and vowel duration values, see Word list for stimulus tape A' and Word list for stimulus tape B' in Appendix A.

SUBJECTS

Group 1

The same children who participated in the first study participated in this study for 3 months. The mean age for children in this group at the beginning of the study was 33.2 months and 35.6 at the end.

Group 2

The same children who participated in the first study participated in the first study participated in this study for 1 month. The mean age for children in this group was 22 months.

PROCEDURE

The tape recording procedure used in this study was the same as that used in the second study.

Each child in Group 1 completed Stimulus Tape A' the first month, Stimulus Tape B' the second month, and Stimulus Tape A' again the last month. Each child went through the tape once each month; i.e. each word was uttered twice. Each child in Group 2 completed Stimulus Tape A' twice in the one month; i.e. each word was uttered four times.

Acoustic Analysis of Responses

The responses were analyzed, transcribed and coded exactly as they were in the second study.

RESULTS AND DISCUSSION

The same 5 scoring procedure types used in the first study were used in this study.

Response utterances from the 2 groups formed the only 2 mean ages observed in this study. For Group 2 the mean age was 23 months at session 2. For Group 1, the mean age was 34 months over sessions 8, 9, 10.

The vowel durations were treated separately for the story words and the constant /#p--/ words just as they were in the second study.

STATISTICAL ANALYSIS OF RESPONSES

A statistical analysis was done on the vowel durations produced by the 3 children from Group 2. Only the responses for the children in Group 2 were used in this statistical analysis, not Group 1, because the former had a minimum of 3 observations per child per word per session, and the latter had only 1 or 2. Only responses from scoring procedure type 1 (All response constants/stimulus) were used. In the responses used, approximately 16% of the final response consonants were incorrect.

To find out if the children were following the vowel duration of the stimulus tape, a completely repeated measures analysis of variance test was performed on the difference between the children's mean vowel durations and those on the tape with the design, word set (2) by manner (2) by voicing (2).

None of the factors tested were shown to be significantly different from those on the stimulus tape at the $p < .05$ level. However, the difference for voicing was at the $p < .06$ level, ($F(1,2) = 15.23$, $p < .06$). Thus, the main factor which was being tested (voicing) was a borderline case. This will be further discussed later under the descriptive analysis.

To test for significant differences in the actual vowel durations produced by the children, a completely repeated measures analysis of variance test was performed on the children's vowel duration means with the same design which was used above.

In the children's utterances, vowel duration was significantly greater before stimulus fricatives than before stimulus stops ($F(1,2) = 63.61$, $p < .05$). The children's mean vowel duration before stops (stimulus tape values given in parenthesis) was 235 (325) and before fricatives was 334 (410). It was expected that manner of articulation would test significantly different, however, because it was different on the stimulus tape.

In the children's utterances, vowels were almost significantly longer before final stimulus voiced consonants than before final stimulus voiceless consonants ($F(1,2) = 15.23$, $p < .06$). The children's mean vowel duration before voiceless consonants was 229 (367) and before voiced consonants, 339 (367). The children did produce the correct voiceless-to-voiced ratio overall, of .67 vs. that on the tape which was 1.00. Thus, with a probability level of $p < .06$, it seems that the children were really not imitating the exact vowel durations on the tape but were producing the utterances with a more normal vowel duration pattern to which they were accustomed, as described in the first and second studies.

DESCRIPTIVE ANALYSIS OF RESPONSES

Vowel duration in relation to voicing of final stops

Final stops after /i/ in story words. Table 22 lists the incorrect final response consonants substituted in /fit/ and /sid/. The same types of substitutions which were made in the first and second studies for these words were also made in this study. The voiceless affricate /ts/ was the main substitution for /t/ and the voiceless stop /t/ was the main substitution for the voiced stop /d/.

Table 22
Third study, children's responses to taped stimuli of abnormal equal duration.
Incorrect response consonants and missing responses
for /i/ before stops

Sess. No.	Mean Age (mo.)		/fit/ V1.st.	/sid/ Vd.st.	/pip/ V1.st.	/pib/ Vd.st.
2	23	Inc. resp. cons.	1/ts/	5/t/	0	3/p/
		No. inc. resp.	1	5	0	3
		% inc. resp.	8%	41%	0%	25%
		No. missing resp.	0	0	0	0
		% missing resp.	0%	0%	0%	0%
8-10	34	Inc. resp. cons.	0	0	0	6/m/
		No. inc. resp.	0	0	0	6
		% inc. resp.	0%	0%	0%	16%
		No. missing resp.	4	4	4	4
		% missing resp.	11%	11%	11%	11%

Despite the incorrect production of some of the final response consonants, scoring procedure type 1 on Table 23 and Figure 25 shows that correct differential vowel duration was produced by both groups of children at 23 and 34 months of age. The voiceless-to-voiced ratio was .72 at 23 months, and .75 at 34 months. The same pattern is seen in scoring procedure types 2 and 3.

Scoring procedure types 4 and 5 are listed in Table 23 and displayed on Figure 25. The same general pattern which was seen in Type 4 in the other two studies is seen also in Type 4 in this study. However, this is not the case for scoring procedure type 5 for children at 23 months. Figure 26 shows that vowels produced with incorrectly substituted voiceless stops for voiced stop /d/ were closer in duration to that for voiceless stops used correctly, than with voiced stops used correctly. Thus, the vowel duration produced here was appropriate for the final response consonant, not the final stimulus consonant. This is contrary to the pattern set for final consonant substitutions in the other two studies.

There were 5 instances of /t/ substitutions for /d/, 3 of these by child 8 (black), and 2 of these by child 9 (white). Both children exhibited the same pattern in vowel duration values for the substituted consonant where vowel duration was appropriate for the response consonant, not the stimulus consonant. This may be due to perceptual confusion in the unusually long duration for these

Table 23

Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration (msec) for /i/ before stops in /fit/, /sid/, as a function of children's age

Stim. tape: Vl. st. /fit/ 315, Vd. st. /sid/ 315, Vl./Vd. Ratio 1.00

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
2	7	25	198	315	.63	198	315	.63	198	315	.63	---	---	---	---
2	8	22	256	287	.89	256	330	.77	256	330	.78	---	273	255	---
2	9	22	166	266	.62	168	348	.48	156	348	.45	195	185	185	---
2	Mean	23	207	290	.72	207	330	.63	203	330	.62	195	229	220	---
8-10	1	35	345	456	.76	345	456	.76	345	456	.76	---	---	---	---
8-10	2	35	193	263	.73	193	263	.73	193	263	.73	---	---	---	---
8-10	3	33	349	468	.75	349	468	.75	349	468	.75	---	---	---	---
8-10	4	32	208	228	.91	208	228	.91	208	228	.91	---	---	---	---
8-10	5	35	354	450	.79	354	450	.79	354	450	.79	---	---	---	---
8-10	6	35	228	364	.62	228	364	.62	228	364	.62	---	---	---	---
8-10	Mean	34	279	372	.75	280	372	.75	279	372	.75	---	---	---	---

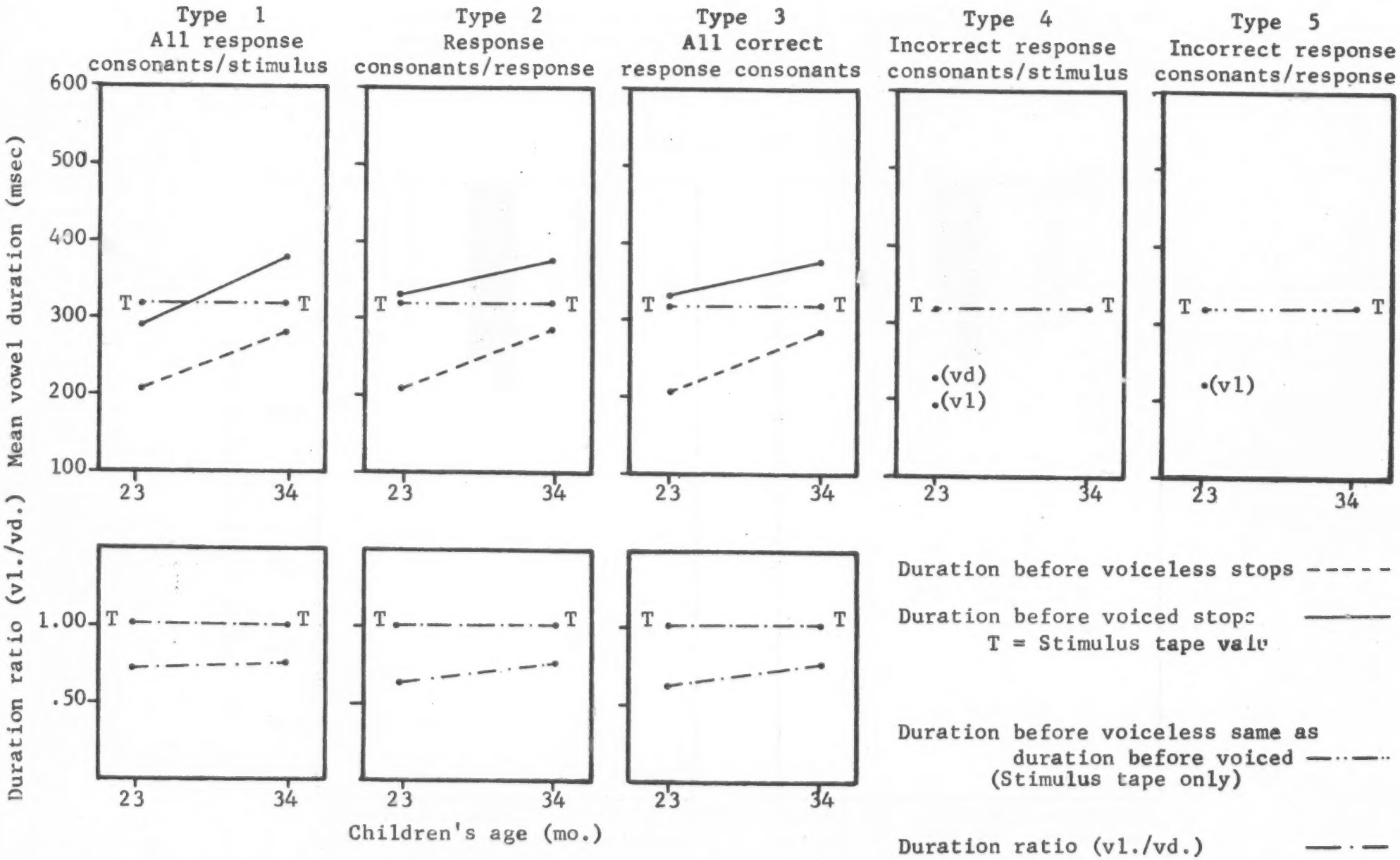

Fig. 25 Third study, children's responses to taped stimlui of abnormal equal duration. Mean vowel duration and duration ratio for /i/ before stops in /fit/, /sid/, as a function of children's age.

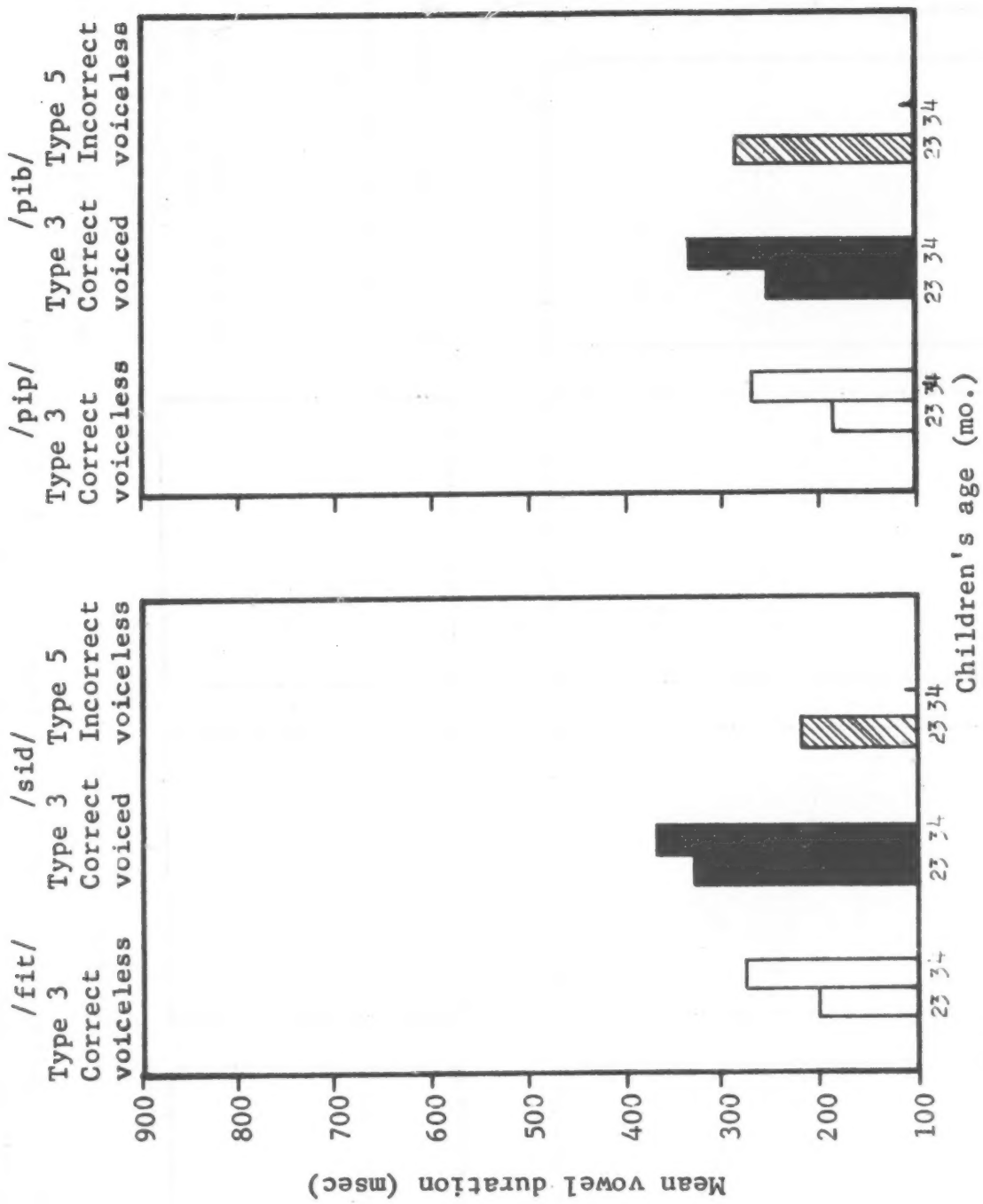

Fig. 26 Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration for /i/ before correctly used voiceless and voiced stops and before voiceless stops substituted for voiced stops, as a function of children's age.

meaningful story words on the stimulus tape. Differential vowel duration has been shown to be a perceptual cue to final voiced consonants in experiments with meaningful words where adult speakers of English were used (Denes, 1955). Thus, when the children made devoicing errors here, it was possible they thought they were actually trying to articulate a different stimulus consonant from the one actually presented to them.

This same type of devoicing confusion is seen for the story words with final fricatives in this study, but never for the perhaps meaningless constant /#p--/ words for either the stops or the fricatives.

The mean vowel duration values produced by the children in this study are compared to those in the first and second studies in the table below (scoring procedure type 1) and in Fig. 17 in Chapter 3, p. 73. Stimulus tape values are in parenthesis.

Mean Age (mo.)			Mean vowel duration (msec) /fit/ (315)			/sid/ (315)		
Abnormal Tape	Normal Tape	Pict.	Ab. Tape	Norm. Tape	Pict.	Ab. Tape	Norm. Tape	Pict.
23	22	22	207	168	180	290	332	346
34	32	34	279	211	269	372	408	424

This shows that the children in the 23 month age group were increasing the duration before voiceless stops in this condition by pulling it towards the duration for the stimulus tape, but the stimulus duration of 315 was inordinately long before voiceless stops for them and at this age they were far from it in their productions. For vowel duration before voiced stops, the 315 msec duration on the tape was much more realistic as the produced value of 290 shows. The

children in the 34 month age group came much closer to the duration before voiceless stops than had those in the 23 month age group but their vowels before voiceless stops in the previous studies were also much longer than those for the 23 month old children. The children at 34 months shortened vowels before voiced fricatives from the values produced in previous studies to make it closer to the tape values.

Final stops after /i/ in constant /#p--/ words. Table 22 shows there were no incorrect final response consonants substituted for final /p/. The most common substitutions for /b/ were /p/ and /m/. Scoring procedure types 1, 2, 3 and 4 in Table 24 and Fig. 27 show a pattern similar to that for the story words with final stops.

Only 1 child, child 8, actually did imitate the durations on the tape and she produced a voiceless-to-voiced ratio near 1 or greater. She did this at age 22 months for these constant /#p--/ words where the duration on the tape was 335 msec for both /pip/ and /pib/. Under scoring procedure type 1 the child produced vowel duration before voiceless stops at 265, and before voiced stops at 281, with a .94 ratio; under scoring procedure type 2, 274, 265, with a 1.04 ratio; and under scoring procedure type 3, 265, 265, with a 1.00 ratio. This child spoke black dialect, however, and some features in the parental model were different from those for the other children of white dialect in the study as mentioned in footnote 7 in Chapter 2. This child also made frequent use of voiceless consonants for voiced consonants. She did so for 62% of her "voiced" consonant responses in this study. It is possible, thus, that since

Table 24

Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration (msec) for /i/ before stops in /pip/, /pib/, as a function of children's age

Stim. tape: V1. st. /pip/ 335, Vd. st. /pib/ 335, V1./Vd. Ratio 1.00

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim V1.	Vd.	Rat.	Type 2 Response cons/resp V1.	Vd.	Rat.	Type 3 All correct resp cons V1.	Vd.	Rat.	Type 4 Inc R cons/S V1.	Vd.	Type 5 Inc R cons/R V1.	Vd.
2	7	25	140	230	.61	140	230	.61	140	230	.61	---	---	---	---
2	8	22	265	281	.94	274	265	1.04	265	265	1.00	---	286	286	---
2	9	22	158	256	.62	158	256	.62	158	256	.62	---	---	---	---
2	Mean	23	188	256	.73	191	250	.76	188	250	.75	---	286	286	---
8-10	1	35	402	459	.87	402	---	---	402	---	---	---	459	---	---
8-10	2	35	215	290	.74	215	290	.74	215	290	.74	---	---	---	---
8-10	3	33	259	432	.60	259	432	.60	259	432	.60	---	---	---	---
8-10	4	32	200	248	.81	200	248	.81	200	248	.81	---	---	---	---
8-10	5	35	318	376	.84	318	376	.84	318	376	.84	---	---	---	---
8-10	6	35	223	318	.70	223	318	.70	223	318	.70	---	---	---	---
8-10	Mean	34	269	354	.76	269	333	.81	269	333	.81	---	459	---	---

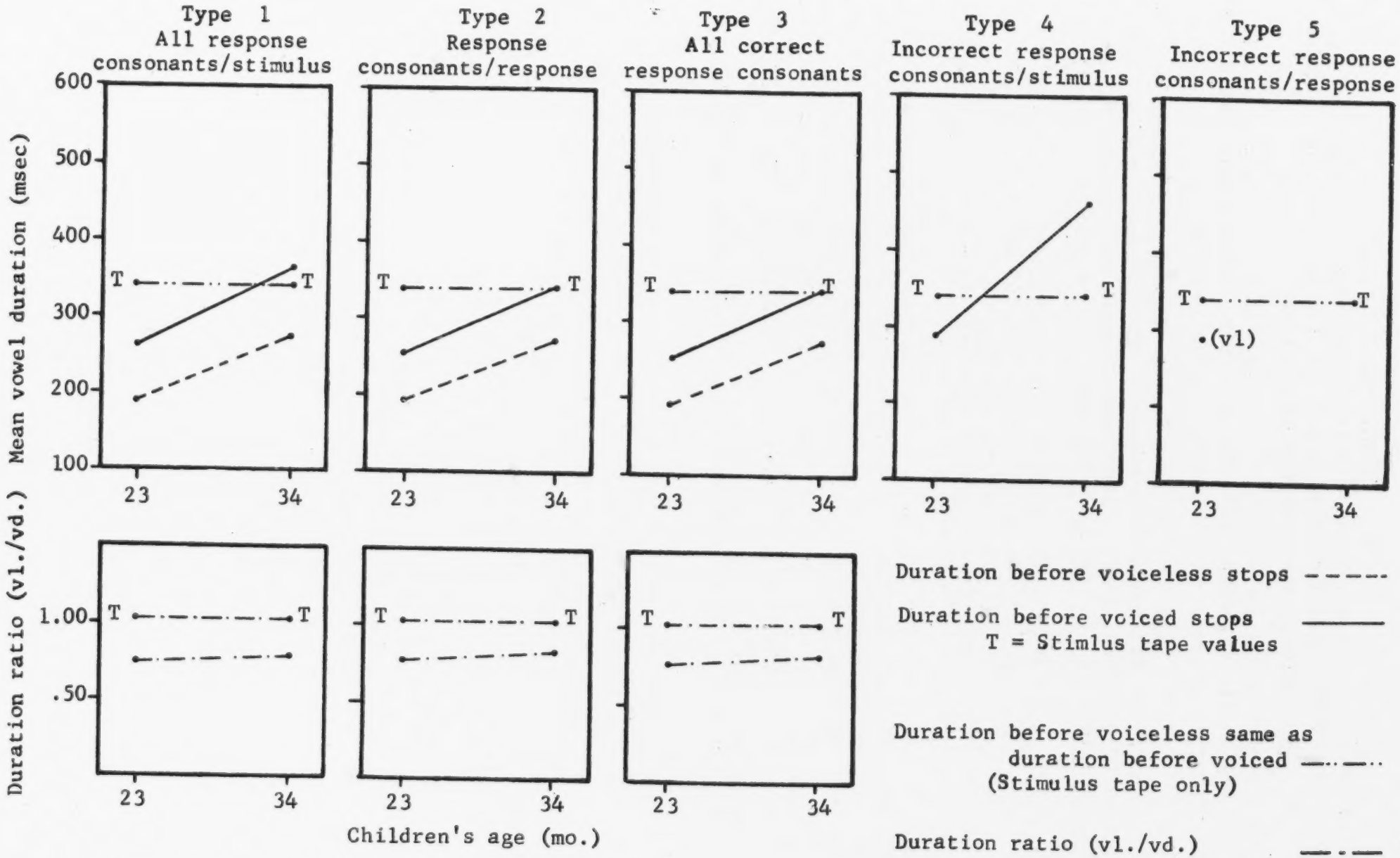

Fig. 27 Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration and duration ratio for /i/ before stops in /pip/, /pib/, as a function of children's age.

the child rarely produced final voiced consonants, that increased vowel duration was not associated with final voiced consonants for her and thus she had no problems imitating the abnormal equal durations for these unfamiliar words. Perhaps she had no internal pattern which dictated increased vowel duration before voiced consonants because she rarely used voiced consonants in final position.

Scoring procedure type 5 differs from that for the story words with stops in this study, in that as shown on Fig. 26, the vowel duration before voiceless stops used incorrectly for voiced stops was closer to that for the correctly used voiced stops than to that for the voiceless stops. However, all the devoicing substitutions here were contributed by child 8. These /#p--/ words may have been meaningless to the child and thus, perceptually, they may have been processed differently from the story words under these conditions. Perhaps the child was not expecting a particular vowel duration for any of these words and was actually processing the entire word at once, identifying the final consonant correctly, and then trying to produce the correct vowel duration according to the total stimulus actually perceived. However, the final voiced consonant was devoiced for some unknown reason, and the vowel duration was closer to that for the stimulus consonant than for the response consonant. This was the case in most devoicing substitutions in the first and second studies for all children.

Vowel duration in relation to voicing of final fricatives

Final fricatives after /i/ in story words. Table 25 lists the incorrect final response consonants substituted in /tiθ/ and /piz/. The same types of substitutions which were made in the first and second studies for these words were also made in this study. The voiceless stop /t/ was substituted for the voiceless fricative /θ/, and the voiceless fricative /s/ for the voiced fricative /z/.

Despite the incorrect production of some of the final response consonants, scoring procedure type 1 on Table 26 and Fig. 28 shows that correct differential vowel duration was produced by both groups of children at 23 and 34 months of age. The voiceless-to-voiced ratio was .63 at 23 months and .78 at 34 months of age. The same pattern is seen in scoring procedure types 2 and 3.

Scoring procedure types 4 and 5 are listed in Table 27 and Fig. 28. The same general pattern which was seen in Type 4 in the other studies is also seen here, however, this is not the case for scoring procedure type 5 for children at 23 months. Fig. 29 shows that vowel duration produced with incorrectly substituted voiceless fricatives for the voiced fricative /z/ was closer to that for voiceless fricatives used correctly, than to that with voiced fricatives used correctly. Thus, the vowel duration here was appropriate for the final response consonant, not the final stimulus consonant. There were 3 instances of /s/ substitutions for /z/, 2 of these by child 8 (black) and 1 by child 9 (white). Both children exhibited the same pattern in vowel duration values for the substituted consonants where vowel duration was appropriate for the response consonant, not the stimulus consonant.

Table 25
Third study, children's responses to taped stimuli of abnormal equal duration. Incorrect response consonants and missing responses for /i/ before fricatives

Sess. No.	Mean Age (mo.)		/tiθ/ Vl.fr.	/piz/ Vd.fr.	/pis/ Vl.fr.	/piz/ Vd.fr.
2	23	Inc. resp. cons.	3/t/	2/s/ 1/Ø/	0	2/s/
		No. inc. resp.	3	3	0	2
		% inc. resp.	25%	25%	0%	16%
		No. missing resp.	0	0	0	1
		% missing resp.	0%	0%	0%	8%
8-10	34	Inc. resp. cons.	0	1/Ø/	1/ts/	0
		No. inc. resp.	0	1	1	0
		% inc. resp.	0%	2%	2%	0%
		No. missing resp.	4	4	4	4
		% missing resp.	11%	11%	11%	11%

Table 26

Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration (msec) for /i/ before fricatives in /tiθ/, /piz/, as a function of children's age

Stim. tape: Vl. fr. /tiθ/ 410, Vd. fr. /piz/ 410, Vl./Vd. Ratio 1.00

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim Vl.	Vd.	Rat.	Type 2 Response cons/resp Vl.	Vd.	Rat.	Type 3 All correct resp cons Vl.	Vd.	Rat.	Type 4 Inc R cons/S Vl.	Vd.	Type 5 Inc R cons/R Vl.	Vd.
2	7	25	194	428	.45	194	428	.45	194	428	.45	---	---	---	---
2	8	22	271	395	.69	366	428	.86	375	428	.88	236	362	362	---
2	9	22	310	406	.76	301	453	.66	310	453	.68	---	265	265	---
2	Mean	23	258	410	.63	287	436	.66	292	436	.67	236	314	314	---
8-10	1	35	423	469	.90	423	469	.90	423	469	.90	---	---	---	---
8-10	2	35	258	324	.80	258	324	.80	258	324	.80	---	---	---	---
8-10	3	33	428	536	.80	428	536	.80	428	536	.80	---	---	---	---
8-10	4	32	350	580	.60	350	580	.60	350	580	.60	---	---	---	---
8-10	5	35	460	490	.94	460	478	.96	460	478	.96	---	555	---	---
8-10	6	35	268	409	.66	268	409	.66	268	409	.66	---	---	---	---
8-10	Mean	34	364	468	.78	364	466	.78	364	466	.78	---	555	---	---

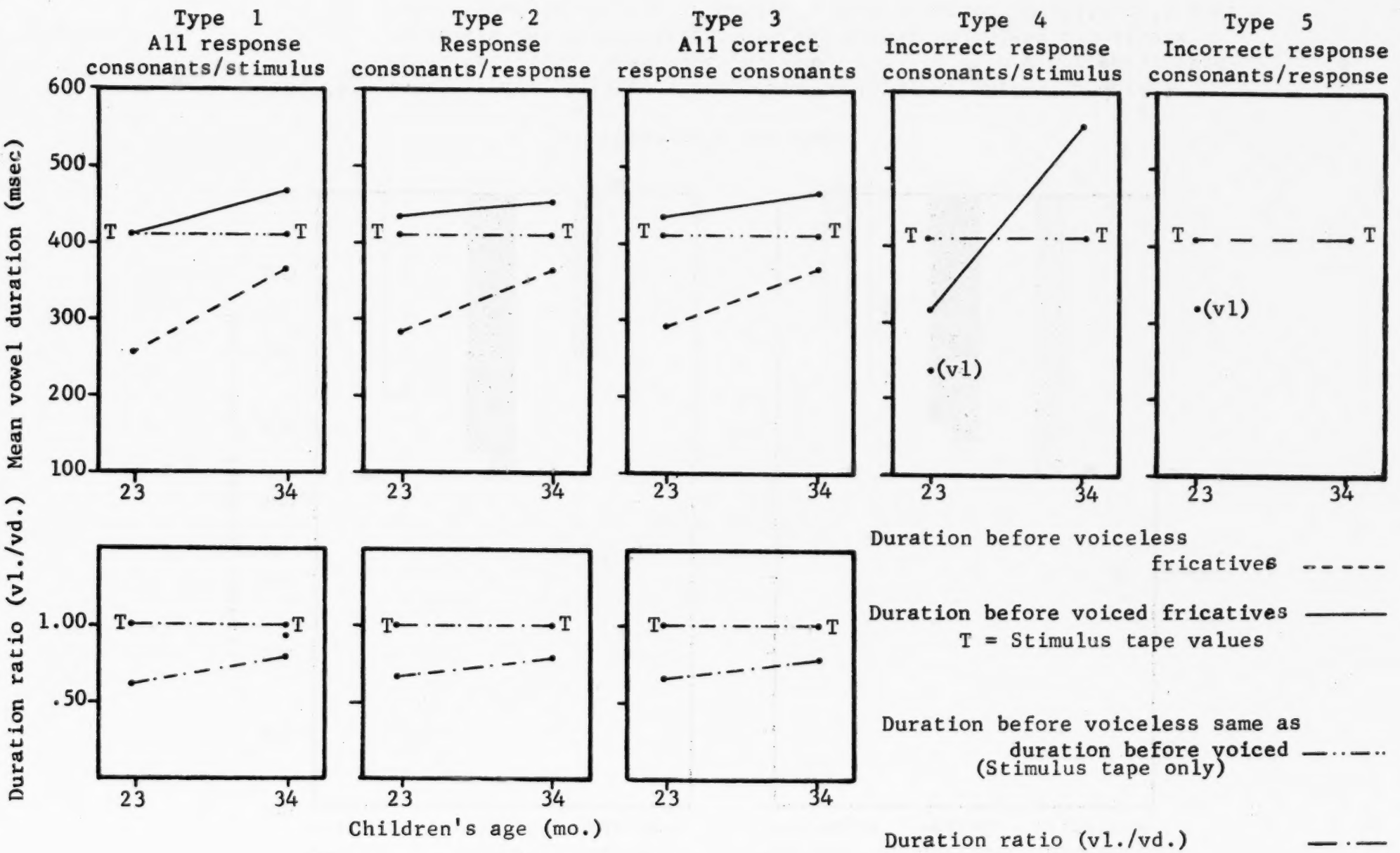

Fig. 28 Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration and duration ratio for /i/ before fricatives in /tiθ/, /piz/, as a function of children's age.

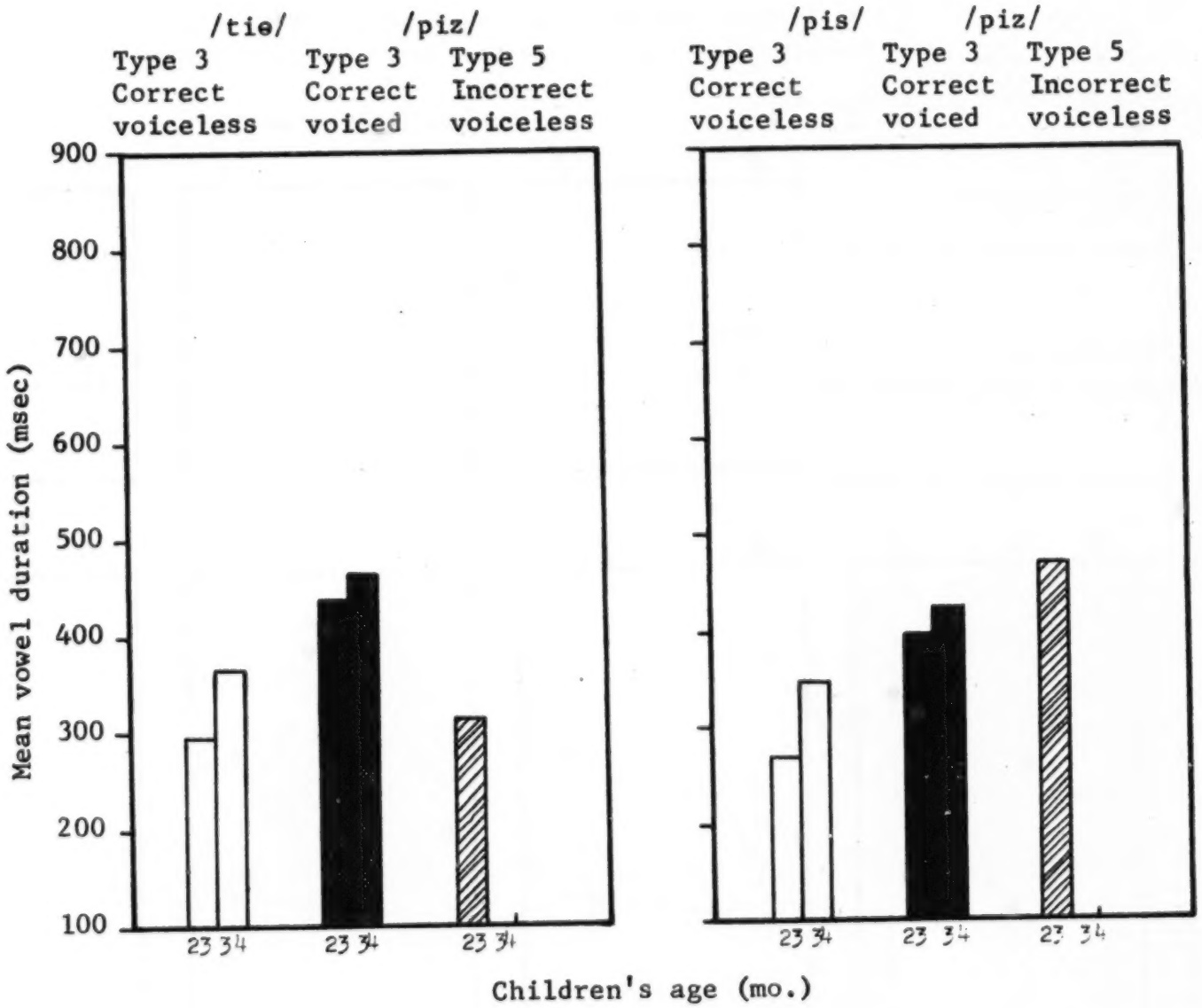

Fig. 29 Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration for /i/ before correctly used voiceless and voiced fricatives and before voiceless fricatives substituted for voiced fricatives, as a function of children's age.

This may be due to the same factors discussed concerning this phenomenon under vowel duration for the story words before final stops.

The mean vowel duration values produced by the children in this study are compared to those in the first and second studies in the table below (scoring procedure type 1) and in Fig. 21 in Chapter 3, p. 83. Stimulus tape values are in parenthesis.

Mean Age (mo.)			Mean vowel duration (msec) /tiθ/ (410)			/piz/ (410)		
Abnormal Tape	Normal Tape	Pict.	Ab. Tape	Norm. Tape	Pict.	Ab. Tape	Norm. Tape	Pict.
23	22	22	258	254	225	410	416	430
34	32	34	364	242	310	468	468	497

This shows that the children at 23 months were not really adjusting at all to the durations on the tape before voiceless fricatives. The duration they produced before voiced fricatives with the tape was the same as the tape and coincidentally, very close to the vowel duration productions before voiced fricatives in the other 2 studies. Thus, it is difficult to say whether the tape was really being imitated or that duration on the tape was a very comfortable duration normally for the children in the study at 34 months. Once again, the durations produced here before the voiceless final consonants were pulled towards those on the tape, just as they were before voiceless stops by these children. The duration before voiced fricatives, however, is very close to that produced in the other studies as well as the tape. Thus, again, it is difficult to say if this duration was influenced by that on the tape or not.

Final fricatives after /i/ in constant /#p--/ words. Table 25 shows that most errors were substitutions for the voiced fricative /z/ and the consonants substituted were the voiceless fricative /s/. Scoring procedure types 1, 2, 3 and 4 in Table 27 and Fig. 30 show a pattern similar to that for the story words with final fricatives.

Child 8 produced the same pattern with these constant /#p--/ words with final fricatives as she had done with the stops. Where the stimulus tape was 410 msec, in scoring procedure type 1 she produced a vowel duration of 395 before voiceless, and 445 before voiced fricatives, with a ratio of .89; in scoring procedure type 2, 420, and 420, with a ratio of 1.00; and in scoring procedure type 3, 395, 420, with a ratio of .94.

Scoring procedure type 4 differs from that for the story words, as shown in Fig. 29. Again, all the devoicing substitutions here were contributed by child 8. The vowel duration before voiceless fricatives used incorrectly for voiced fricatives is closer to that for the correctly used voiced fricatives than to that for the correctly used voiceless fricatives. This pattern also occurred with constant /#p--/ words with final stops. The same explanation offered under constant /#p--/ words with stops would be offered here for that inconsistency between the devoicing responses for the story words and the devoicing responses for the constant /#p--/ words.

Table 27

Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration (msec) for /i/ before fricatives in /pis/, /piz/, as a function of children's age

Stim. tape: V1. fr. /pis/ 410, Vd. fr. /piz/ 410, V1./Vd. Ratio 1.00

Sess No.	Child No.	Age (mo)	Type 1 All resp. cons/stim V1.	Vd.	Rat.	Type 2 Response cons/resp V1.	Vd.	Rat.	Type 3 All correct resp cons V1.	Vd.	Rat.	Type 4 Inc R cons/S V1.	Vd.	Type 5 Inc R cons/R V1.	Vd.
2	7	25	184	358	.51	184	358	.51	184	358	.51	---	---	---	---
2	8	22	395	445	.89	420	420	1.00	395	420	.94	---	470	470	---
2	9	22	222	406	.55	222	406	.55	222	406	.55	---	---	---	---
2	Mean	23	267	403	.66	275	394	.70	267	394	.68	---	470	470	---
8-10	1	35	442	438	1.01	442	438	1.01	442	438	1.01	---	---	---	---
8-10	2	35	274	348	.79	274	348	.79	274	348	.79	---	---	---	---
8-10	3	33	463	540	.86	463	540	.86	463	540	.86	---	---	---	---
8-10	4	32	178	352	.50	200	352	.57	200	352	.57	155	---	---	---
8-10	5	35	451	520	.87	452	520	.87	452	520	.87	---	---	---	---
8-10	6	35	243	356	.68	243	356	.68	243	356	.68	---	---	---	---
8-10	Mean	34	342	425	.80	346	426	.81	346	426	.81	155	---	---	---

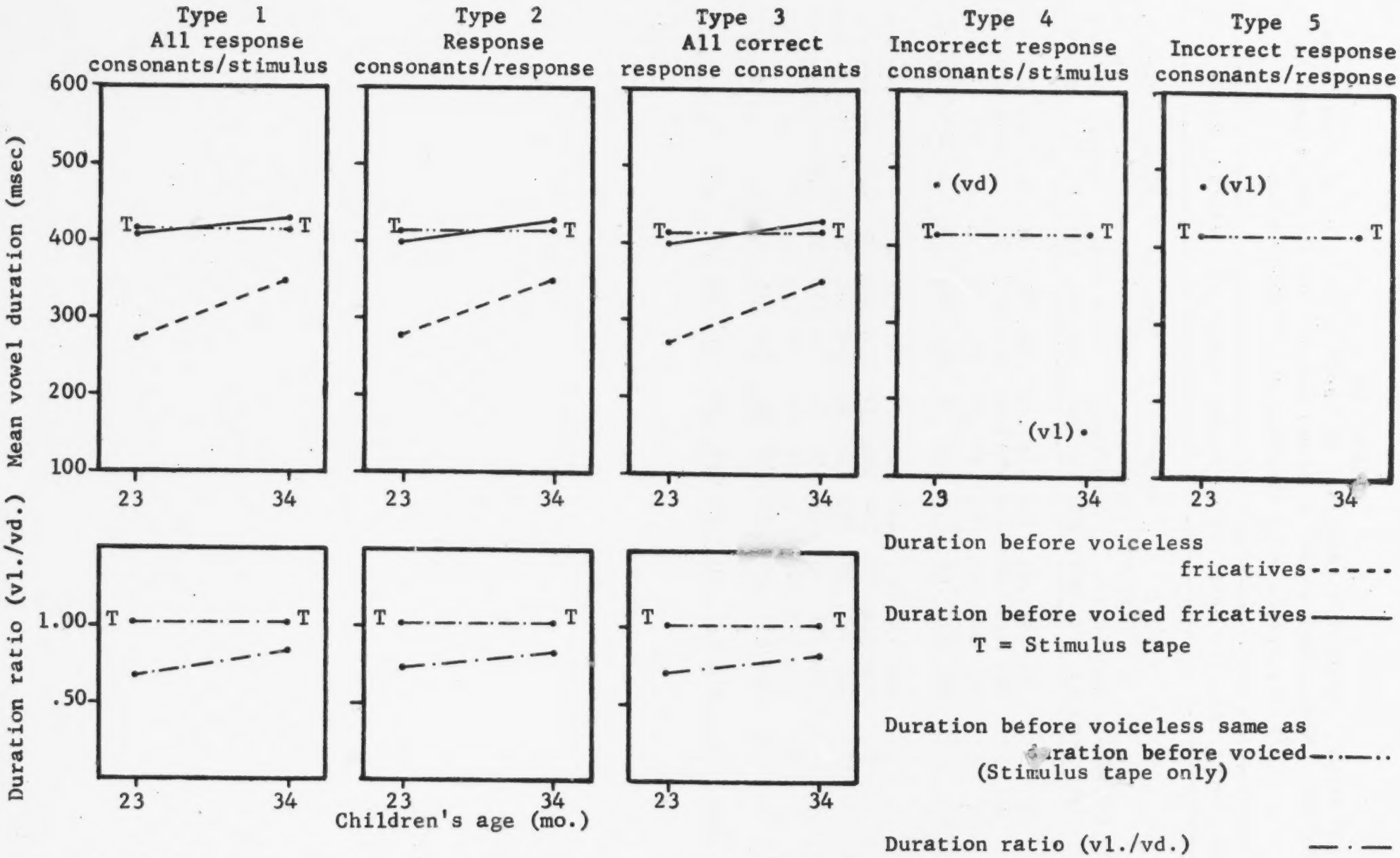

Fig. 30 Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration and duration ratio for /i/ before fricatives in /pis/, /piz/, as a function of children's age.

Vowel duration in relation to manner of articulation of final consonants

Final stops and fricatives in story words. Tables 22 and 25 show the errors produced for stops and fricatives which have been detailed under the separate discussions of stops and fricatives. The manner of production, stop, was never confused with the manner of production, fricative, as was the case for voicing.

Scoring procedure type 1 on Table 28 and Fig. 31 shows that correct differential vowel duration before stops and fricatives was maintained by both groups of children. Those at 34 months were extremely close in matching the overall duration before stops and fricatives with those on the tape. The same was true for scoring procedure types 2 and 3.

The mean vowel duration values produced by the children before stops and fricatives in this study are compared to those in the first and second studies (scoring procedure type 1) in the table below. Stimulus tape values are in parenthesis.

Mean Age (mo.)			Mean vowel duration (msec)					
			Stops (315)			Fricatives (410)		
Abnormal Tape	Normal Tape	Pict.	Ab. Tape	Norm. Tape	Pict.	Ab. Tape	Norm. Tape	Pict.
23	22	22	248	250	263	334	335	328
34	32	34	326	310	346	417	356	403

As mentioned above, the children at 34 months were very close in matching the duration before stops and fricatives on the stimulus tape, but this duration was also very close to their other productions of /i/ before stops and fricatives under the other 2 stimulus conditions in the preceding studies. The 24-month-old children were also producing

Table 28

Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration (msec) for /i/ before stops and fricatives in the story words, as a function of children's age

			Stim. tape: Stops 315, Fricatives 410		
			Type 1	Type 2	Type 3
			All resp.	Response	All correct
Sess	Child	Age	cons/stim	cons/resp	resp cons
No.	No.	(mo)	St. Fr.	St. Fr.	St. Fr.
2	7	25	256 311	256 311	256 311
2	8	22	272 333	292 397	293 401
2	9	22	216 358	258 377	252 382
2 Mean		23	248 334	269 362	267 364
8-10	1	35	400 446	400 446	400 446
8-10	2	35	228 291	228 291	228 291
8-10	3	33	408 482	408 482	408 482
8-10	4	32	218 465	218 465	218 465
8-10	5	35	402 476	402 469	402 469
8-10	6	35	296 338	296 338	296 338
8-10 Mean		34	326 417	326 415	326 415

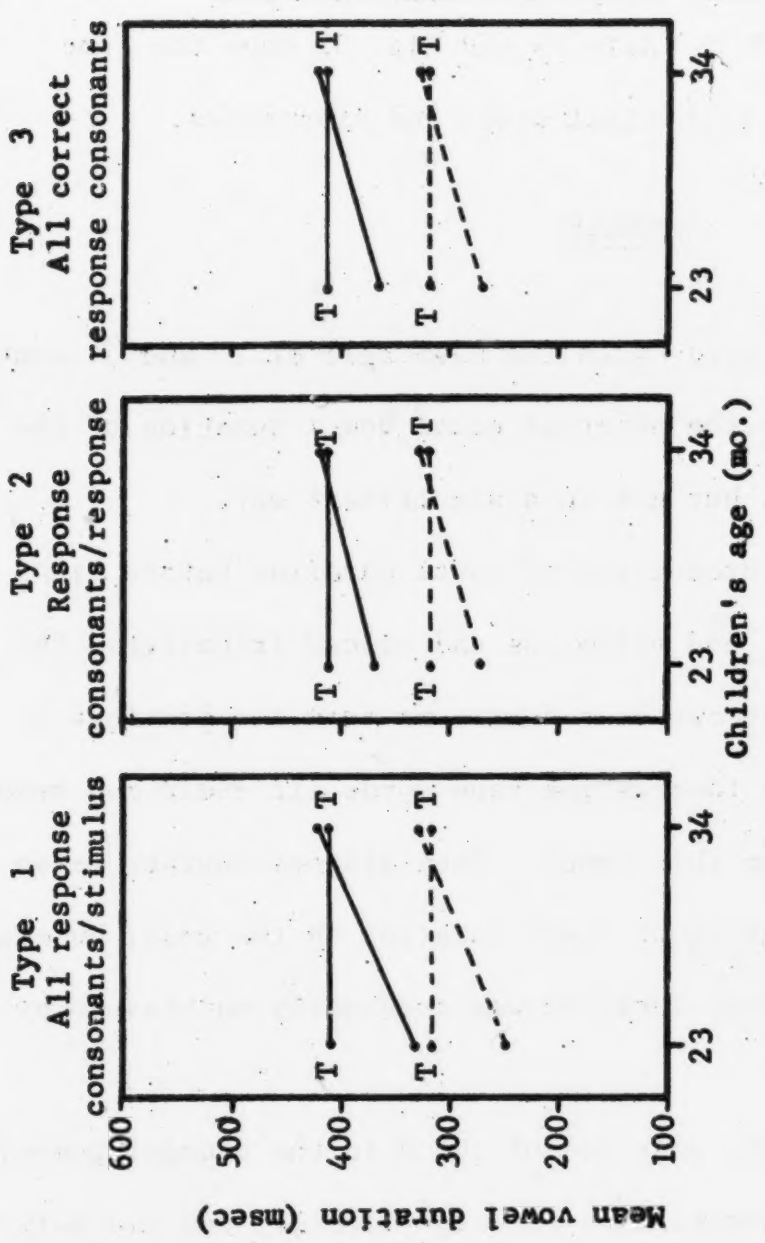

Fig. 31 Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration for /i/ before stops and fricatives in the story words, as a function of children's age.

duration before stops and fricatives which were natural for them, and these durations were shorter than those on the stimulus tape so they showed a greater deviation from the tape than did the 34-month-old children.

Final stops and fricatives in constant /#p--/ words. Scoring procedure types 1, 2, and 3 in Table 29 and Fig. 32 show the same pattern as the story words with final stops and fricatives.

SUMMARY

The children in this study with the mean ages of 23 and 34 months were somewhat influenced by the abnormal equal vowel duration of the stimulus words on the tape, but not in a significant way.

In most instances of production of vowel duration before final voiceless and voiced stops, and voiceless and voiced fricatives, the children deviated from their own mean durations from the previous 2 studies for the story words towards the tape words (if their own means were different from those on this tape). They did not deviate to an extent which would match the equal vowel duration on the tape, however, and correct differential vowel duration was constantly maintained by most of the children.

Child 8 (black) was the only one of the 3 in the younger group, Group 2, who imitated the duration on the tape closely, and she only did it with the perhaps unfamiliar constant /#p--/ words. This child had contributed 76% of the devoicing errors for the younger group in this study. This might indicate that she was still in an early stage of differential vowel duration development where it was first purely

Table 29

Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration (msec) for /i/ before stops and fricatives in the constant /#p--/ words, as a function of children's age

Stimulus tape: Stops 335, Fricatives 410								
			Type 1 All resp.		Type 2 Response		Type 3 All correct	
Sess No.	Child No.	Age (mo)	cons/stim St.	Fr.	cons/resp St.	Fr.	resp cons St.	Fr.
2	7	25	185	270	185	270	185	270
2	8	22	273	420	270	420	265	408
2	9	22	208	314	208	314	208	314
2 Mean		23	222	335	220	335	219	330
8-10	1	35	430	440	402	440	402	442
8-10	2	35	252	311	252	311	252	311
8-10	3	33	346	502	345	502	345	502
8-10	4	32	224	265	224	276	224	276
8-10	5	35	347	486	347	486	347	486
8-10	6	35	270	300	270	300	270	300
8-10 Mean		34	312	384	301	386	301	386

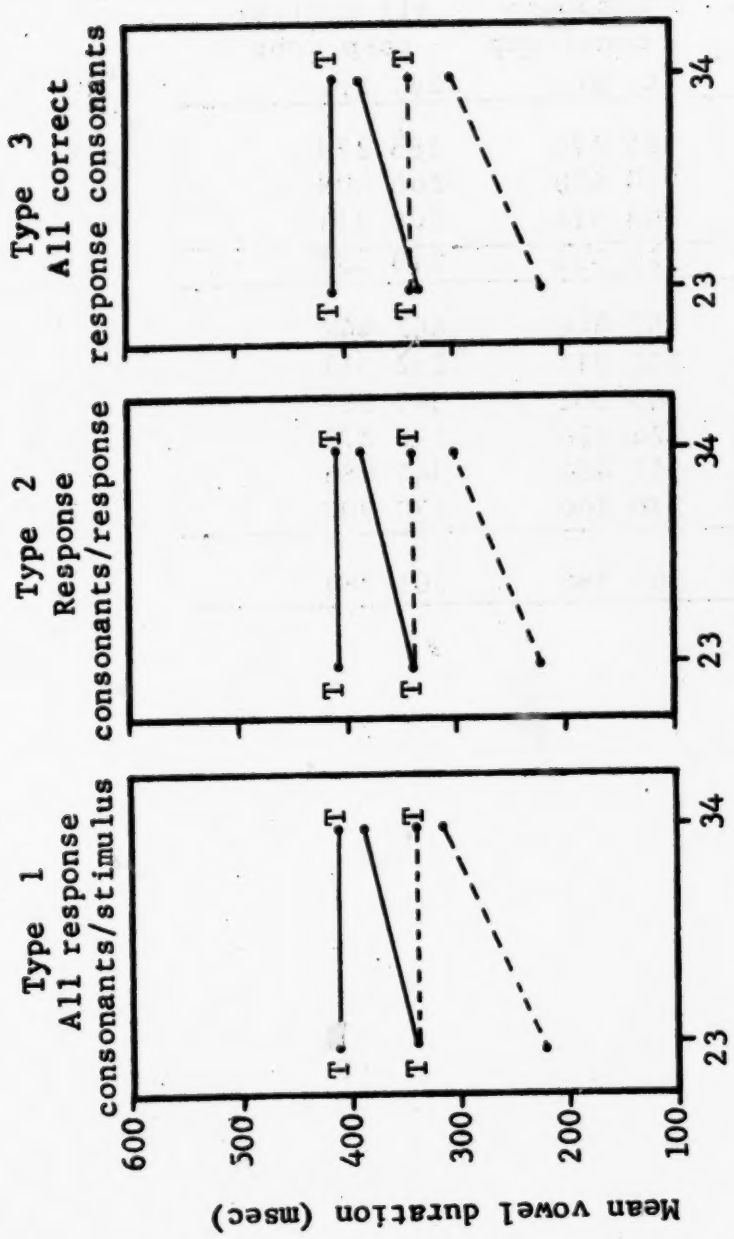

Fig. 32 Third study, children's responses to taped stimuli of abnormal equal duration. Mean vowel duration for /i/ before stops and fricatives in the constant /#p--/ words, as a function of children's age.

imitated. Then, after proper control of final consonant voicing was learned, the phenomenon of increased duration was paired with a final voiced consonant. However, not until this pairing was established, did the child consistently produce correct differential vowel duration, regardless of the duration on a stimulus tape, as was the case for the other 2 children in the 23 month age group who together contributed the other 24% of the devoicing errors. None of the children in the 34-months age group, all of whom had control of voicing of final consonants in the majority of instances, showed any imitation of the tape to the extent that child 8 did.

Thus, it is interesting to speculate that the one child's close imitation of the ratios on the tape were due to her lack of proper control of final voicing, but it is not known, of course, if this is the case. There are certainly other plausible reasons which may be connected with her black dialect which caused her to respond totally differently from the other 8 children with the constant /#p--/ words.

The majority of the children at 23 months did not imitate the abnormal equal durations on the stimulus tape and none of the children in the 34 month age group did. Apparently for most children, once the pattern has been established of production of final voiced consonants with increased vowel duration, it is not likely to be altered by presentation of any stimuli, familiar or unfamiliar, which violate this pattern.